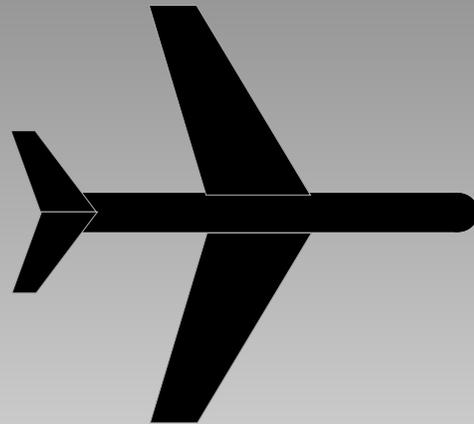


Flight Simulation
Year in Review
FY98

Foreword

This document is the Fiscal Year 1998 Annual Performance Summary of the NASA Ames Vertical Motion Simulation (VMS) Complex and the Crew Vehicle Systems Research Facility (CVSRF). It is intended to report to our customers and management on the more significant events of FY98. What follows are an Executive Summary with comments on future plans, the FY98 Simulation Schedule, a projection of simulations to be performed in FY99, performance summaries that report on the simulation investigations conducted during the year, and a summary of Technology Upgrade Projects.



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11 December 1998

Acknowledgment

Special thanks to Matt Blake, Dave Carothers, Girish Chachad, Bill Chung, Ron Gerdes, Scott Gilliland, Jennifer Goudey, Scott Malsom, Julie Mikula, Bob Shiner, and Barry Sullivan for contributions made to the production of this document.

About the Cover

Front cover: The Advanced Concepts Flight Simulator examined a new flight system with the potential to improve the safety and efficiency of airport surface operations in low visibility. This cockpit navigation and guidance system displays taxi routes on both a head-up display (pictured) and an electronic moving map. Taxi runs made with the system were rapid and error free. (For more information, see page 35.)

Back cover: The Vertical Motion Simulator has a key role in the development of the next-generation fighter, which will be flown by three branches of the U.S. military. Two proposed versions of the Joint Strike Fighter were simulated: Boeing's X-32 (left) and Lockheed Martin's X-35 (right). (For more information, see pages 16 and 19.)

Table of Contents

Foreword	3
Executive Summary	6
FY98 Simulation Schedule	9
FY98 VMS Project Summaries	10
FY98 CVSRF Project Summaries	11
FY99 VMS Simulation Projects	12
FY99 CVSRF Simulation Projects	13
Vertical Motion Simulator Research Facility	15
Boeing B1, A1, A2	16
Simulation Fidelity Requirements 5	17
Civil Tiltrotor 7	18
Lockheed Martin	19
Space Shuttle Vehicle 1	20
Helicopter Maneuver Envelope Enhancement 5	21
Slung Load 5	22
Simulation Fidelity Requirements 6	23
High Speed Civil Transport Design & Integration	24
High Speed Civil Transport A7	25
High Speed Civil Transport A7B	26
Partial Authority Flight Control Augmentation	27
Space Shuttle Vehicle 2	28
Crew-Vehicle Systems Research Facility	31
Decision Making	32
Propulsion Controlled Aircraft 3	33
Obstacle Free Zone 1, 2	34
Taxiway Navigation and Situation Awareness	35
Air-Ground Integration (Free Flight 3)	36
Turbulence for Precipitous Terrain	37
Fatigue Countermeasures	38
Propulsion Controlled Aircraft 4 (Ultralite)	39
Advanced Automation Qualification	40
Technology Upgrade Projects	43
Virtual Laboratory	44
Out-the-Window 2000 Plus	45
Host Computer Upgrade	46
Real-Time Network Upgrade	47
Bosnia Visual Database	48
Joint FAA/Army/NASA Interoperability Demonstration	49
Flight Management System Upgrade	50
Communications System Upgrade	51
List of Acronyms	52
Appendix 1	54

Executive Summary

This Annual Report addresses the major simulation accomplishments of the Aviation Systems Research, Technology, and Simulation Division of the NASA Ames Research Center. The Ames Simulation Facilities, contained in two separate buildings at Ames Research Center and operated by this Division, consist of the Crew Vehicle Systems Research Facility (CVSRF) and the Vertical Motion Simulation (VMS) Complex. The CVSRF is comprised of a Boeing 747-400 Simulator, the Advanced Concepts Flight Simulator (ACFS), and an Air Traffic Control (ATC) simulator. The VMS Complex is comprised of the Vertical Motion Simulator (VMS), five Interchangeable Cockpits (ICABs), and two fixed-base simulation labs. A brief description of these facilities follows this report in Appendix 1.

From a Management perspective, Fiscal Year 1998 was dominated by several important events. First was the achievement of ISO 9001 Certification in May. This certification was achieved after two years of planning and effort by the entire staff, civil service and contractor. A second significant event was the organizational transition completed in July with the forming of the new Aviation Systems Research, Technology, and Simulation Division (AF). This completes the changes begun when the Wind Tunnels became a separate Division within Code F. The final activity has been the continuing efforts to streamline and reduce facility operations costs at NASA.

In addition to these activities, paramount to Division operations has been the continuing commitment to uncompromised excellence in the development and production of efficient, high-fidelity, safe, real-time piloted flight simulations. The Division has also continued to aggressively modernize in order to maintain reliability, our competitive edge, and our responsiveness to Users' needs. The staff places very high value on customer relations and has successfully provided highly responsive, cost-effective, value-added simulation support to all simulation customers.

The purpose of this document is to briefly describe our accomplishments of the past year. Its outline includes the Executive Summary, Simulation Schedule for FY98, Planned Projects for FY99, VMS Project Summaries, CVSRF Project Summaries, and Technology Upgrade Projects. The Project Summaries sections state the goal of each simulation and present high level results. Researchers and Pilots from NASA and private industry are identified as well as simulation engineers from the staff. The Technology Upgrade Projects section reports changes made in order to keep our simulation facilities state-of-the-art. Finally, a List of Acronyms is included for the reader's convenience.

Notable accomplishments for FY98 include the following:

All simulation experiments conducted at Ames support significant research that is responsive to the needs of the Nation with a focus on applied aeronautics research. Diversity, fidelity, and breadth of simulation distinguish the research projects conducted at Ames, as can be seen by reviewing the Project Summaries sections of this report.

There were 26 major simulation experiments conducted in the flight simulation laboratories in FY98. These simulations reflect a continued concentration on NASA's focused programs such as High Speed Research (HSR), Advanced Subsonic Technology (AST), NASA's Space Operations, and FAA/NASA Airspace Operations Systems. Support was also provided to other Government research, with emphasis on the Army Rotorcraft and Joint Strike Fighter (JSF) programs. In addition, there were several technology upgrade projects either completed or with significant progress being accomplished during the year.

Technology upgrade projects for the past year include:

Within the CVSRF, upgrades to the ACFS Flight Management System and the facilitywide Communications System were completed. An evaluation of the application of the DOD High Level Architecture was also performed in coordination with the Army and FAA.

The VMS completed the conversion to the new ESIG 4530 with the expansion to five channels and its routine use in production operations. In addition, incremental upgrades to the Host Computer systems and the Virtual Laboratory were completed.

Some future plans:

All of the simulation facilities continue to be in high demand. There is a full list of projects for FY99 that build on past research efforts and bring some new activities as well. We will continue our tradition of supporting mainstream NASA and national aeronautical development programs, being second to none in state-of-the-art real-time simulation and enabling technologies. Automated tools for simulation and modeling, improvements in graphics and displays, and efficient computational environments are other continuing efforts.

In addition, significant efforts are underway planning the VMS Modernization Project currently scheduled for FY01. The project will replace obsolete mechanical drives and control equipment with state-of-the-art systems. When complete, the VMS will set the standard for low-cost, reliable, high-performance motion.



A. David Jones

Associate Chief-Simulations
Aviation Systems Research, Technology, & Simulation Division



FY98 Project Summaries

VMS Flight Simulation Projects

1. Boeing B1

2. Boeing A1

3. Boeing A2

Sept 1 - 11, May 1 - 4 (FB);

Sept 22 - Oct 17, Oct 20 - 31, May 11 - 29 (VMS)

Aircraft type: X-32 Joint Strike Fighter

Purpose: To support Boeing's design and development process and to further NASA-sponsored research of short takeoff/vertical landing controls.

4. Simulation Fidelity Requirements 5 (SimFR 5)

Nov 3 - 20 (VMS)

Aircraft type: NT-33

Purpose: To evaluate the effectiveness of simulator motion in predicting pilot-induced oscillation.

5. Civil Tiltrotor 7 (CTR 7)

Nov 3 - 20 (FB); Nov 24 - Dec 18 (VMS)

Aircraft type: Civil Tiltrotor

Purpose: To investigate aircraft guidance, terminal flight procedures, and varying environmental conditions for tiltrotor transports.

6. Lockheed Martin

Jan 5 - 15 (FB); Jan 19 - Feb 6 (VMS)

Aircraft type: X-35 Joint Strike Fighter

Purpose: To evaluate control system designs and cockpit display concepts as part of NASA-sponsored short takeoff/vertical landing controls research.

7. Space Shuttle Vehicle 1 (SSV 1)

Feb 9 - Mar 12 (VMS)

Aircraft type: Space Shuttle Orbiter

Purpose: To investigate the Space Shuttle Orbiter hydraulic systems, landing systems, and directional control handling qualities and to provide astronaut training.

8. Helicopter Maneuver Envelope Enhancement 5 (HelMEE 5)

Mar 16 - 26 (VMS)

Aircraft type: UH-60 Black Hawk helicopter

Purpose: To continue research into predicting helicopter flight envelope limits and communicating those limits to the pilot.

9. Slung Load 5 (SLOAD 5)

Mar 30 - Apr 9 (VMS)

Aircraft type: CH-47D Chinook helicopter

Purpose: To improve handling qualities criteria for cargo helicopters in slung load operations and to refine techniques for measuring those criteria.

10. Simulation Fidelity Requirements 6 (SIMFR 6)

Apr 13 - May 7

Purpose: To gather data for the development and validation of a pilot model to characterize how a pilot processes and responds to visual and motion cues.

11. High Speed Civil Transport Design & Integration (HSCT D&I)

June 1 - 4 (FB); June 8 - 26 (VMS)

Aircraft type: High Speed Civil Transport

Purpose: To investigate design issues related to new flight deck requirements for a High Speed Civil Transport aircraft.

12. High Speed Civil Transport A7 (HSCT A7)

13. High Speed Civil Transport A7B (HSCT A7B)

June 29 - Aug 7, Sept 21 - Oct 2 (VMS)

Aircraft type: High Speed Civil Transport

Purpose: To investigate the handling qualities, control requirements, and guidance concepts for the Guidance and Flight Control Team of the HSR Program.

14. Partial Authority (PAFCA)

July 20 - Aug 7 (FB); Aug 10 - 27 (VMS)

Aircraft Type: UH-60 Black Hawk helicopter

Purpose: To investigate the flying qualities improvement potential of a Partial-Authority Flight Control System.

15. Space Shuttle Vehicle 2 (SSV 2)

Aug 31 - Sept 18 (VMS)

Aircraft type: Space Shuttle Orbiter

Purpose: To train crews of upcoming missions and astronaut candidates.

VMS Technology Upgrades

1. Virtual Laboratory (VLAB)

Purpose: To develop, integrate, and operate a remote-access system that facilitates interactive participation for off-site VMS customers.

2. Out-the-Window 2000 Plus

Purpose: To greatly enhance the real-time out-the-window image capabilities of the VMS.

3. Host Computer Upgrade

Purpose: To replace existing host computers with new systems to meet the simulation needs of the VMS well into the new century.

4. Real-Time Network Upgrade

Continued next page...

FY98 Project Summaries

Purpose: To increase network performance, functionality, and configurability while allowing for future upgrades to developing network technologies.

5. Bosnia Visual Database

Purpose: To develop a visual database representing the area around Tuzla, Bosnia for use in U.S. Army simulators.

CVSRF Flight Simulation Projects

1. Decision Making

Oct 1 - Oct 6 (B747)

Purpose: To examine flight crew communications in low- and high-risk situations and how these risks affect pilot decision making.

2. Propulsion Controlled Aircraft 3 (PCA 3)

Oct 16 - Oct 23 (B747)

Purpose: To examine the use of a low-cost fly-by-throttle control system as a backup primary flight control system for a four-engine transport aircraft in the event of an emergency or malfunction.

3. Obstacle Free Zone 1 (OFZ 1)

4. Obstacle Free Zone 2 (OFZ 2)

Nov 6 - Nov 20, Jan 28 - Feb 11 (B747)

Purpose: To define safe spacing and dimension requirements for new and existing large transport aircraft when conducting aborted takeoffs or balked landings below established decision heights.

5. Taxiway Navigation and Situation

Awareness (T-NASA)

Jan 5 - Feb 17 (ACFS)

Purpose: To improve airport surface operations in bad weather and at night through the use of a head-up display, electronic moving map of the airport area, and electronic data-link of taxi routes directly into the aircraft on-board computer.

6. Air-Ground Integration (Free Flight 3)

Mar 16 - Apr 3 (B747)

Purpose: To evaluate the alert and protected zone airspace definitions for free flight and pilot interpretation of applying visual flight rules right-of-way procedures in an integrated air-ground free-flight environment.

7. Turbulence for Precipitous Terrain

Apr 7 - Jun 2 (B747)

Purpose: To evaluate the ability of pilots to fly through various levels of turbulence in an effort to quantify the

effects of winds and turbulence induced by precipitous terrain.

8. Fatigue Countermeasures

Jun 4 - Jul 13 (B747)

Purpose: To investigate the effectiveness of an in-flight countermeasure to the fatiguing effects of a long, overnight flight and to evaluate new techniques for measuring drowsiness and fatigue.

9. Propulsion Controlled Aircraft 4 (Ultralite)

Aug 10 - Aug 21 (ACFS)

Purpose: To investigate a low-cost fly-by-throttle control system as a backup to the primary flight control system.

10. Advanced Automation Qualification (AAQ)

Sep 21 - Sep 25 (B747)

Purpose: To evaluate the effectiveness of a training curriculum designed to teach flight deck automation concepts and skills to a level of understanding beyond what is currently taught.

CVSRF Technology Upgrades

1. Joint FAA/Army/NASA Interoperability Demonstration

Purpose: To test and evaluate the new High Level Architecture for future use in large teaming experiments by integrating simulators from the three organizations in a joint demonstration.

2. Flight Management System (FMS) Upgrade

Purpose: To enhance the existing ACFS programable FMS to provide a unique world class research system for advanced airspace operations research.

3. Communications System Upgrade

Purpose: To increase the fidelity of the CVSRF simulated radio communication system between the ATC Simulator, the 747-400 Simulator, and the Advanced Concepts Flight Simulator in order to enhance realism.

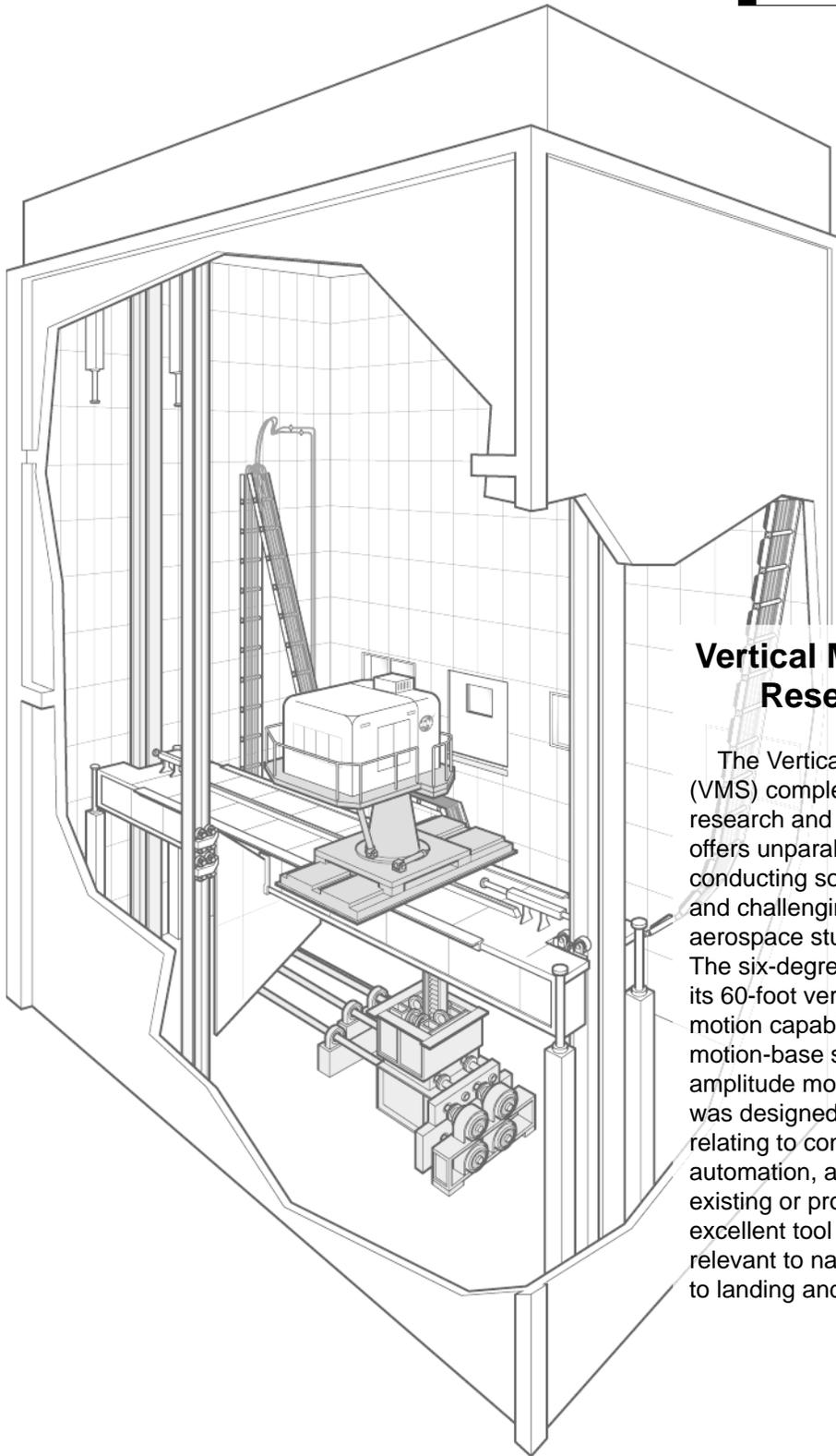
FB - Fixed Base Simulators
VMS - Vertical Motion Simulator
ACFS - Advanced Concepts Flight Simulator
B747 - Boeing 747 Simulator

FY99 VMS Simulation Projects

PROJECT	PROGRAM SUPPORTED	CUSTOMERS	TEST OBJECTIVES
Boeing B2	JSF	Boeing, NASA Ames, US Air Force, Marines & Navy	Investigate handling qualities, control requirements, and guidance concepts for a direct lift type of aircraft.
SimFR 7	Other	NASA Ames	Improve simulation fidelity by evaluating and modifying the motion and visual cueing system performance.
Lockheed 2	JSF	Lockheed, NASA Ames	Investigate handling qualities, control requirements, and guidance concepts for a lift fan type of aircraft.
Lockheed CDA 1	JSF	Lockheed, NASA Ames, US Air Force, Marines & Navy	Investigate handling qualities, control requirements, and guidance concepts for a lift fan type of aircraft.
Space Shuttle Vehicle 1	Space Ops	Rockwell, Honeywell, JSC	Study directional control handling qualities and other Orbiter landing issues.
SimFR 8	Other	Lockheed, NASA Ames	Improve simulation fidelity by evaluating and modifying the motion and visual cueing system performance.
Active Side Stick	DoD (Army)	Army	Investigate application of an active sidestick controller to rotary wing aircraft. Techniques to improve agility and maneuverability.
Civil Tiltrotor 8	AST	FAA, NASA Ames	Continue investigation of tiltrotor aircraft low/noise, noise abatement, and certification issues for terminal area operations.
Boeing B3	JSF	Boeing, NASA Ames, US Air Force, Marines & Navy	Investigate handling qualities, control requirements, and guidance concepts for a direct lift type of aircraft.
Boeing A3	JSF	Boeing, NASA Ames	Investigate advanced flight control system handling qualities, control requirements, and guidance for a direct lift type of aircraft.
Autorotation	SAFOR	Army, NASA Ames	Isolate visual system and motion cueing requirements for performing autorotation maneuvers for helicopter operators.
HSCT A8	HSR	Boeing, NASA, Army	Investigate handling qualities, control requirements, and guidance concepts for a high-speed type of aircraft to be used for civilian transport.
Space Shuttle Vehicle 2	Space Ops	Rockwell, Honeywell, JSC	Study directional control handling qualities and other Orbiter landing issues.
Lockheed 3	Lockheed	Lockheed, NASA Ames	Investigate handling qualities, control requirements, and guidance concepts for a lift fan type of aircraft.
Lockheed CDA 2	DoD	Lockheed, NASA Ames, US Air Force, Marines & Navy	Investigate handling qualities, control requirements, and guidance concepts for a lift fan type, concept demonstrator aircraft.

FY99 CVSRF Simulation Projects

PROJECT	PROGRAM SUPPORTED	CUSTOMERS	TEST OBJECTIVES
CTAS/FMS Data-link	TAP (ACFS)	NASA Human Factors Division	Investigate pilot performance utilizing automatic data-link of CTAS approaches into the on-board Flight Management Computer System (FMS).
Propulsion Controlled Aircraft (PCA) Ultralite	PCA (747-400)	NASA Ames Computational Sciences Div., NASA Dryden	Evaluate the use of a low-cost fly-by-throttle control law system as an emergency backup flight control system in the event of a hydraulic system failure.
Cockpit Display of Traffic Information (CDTI)	AATT (747-400)	NASA Human Factors Division	Examine the use of advanced self separation and traffic and collision avoidance system display symbology in support of free flight.
FANS Data-Link	NASA/FAA (747-400)	NASA Human Factors Division, FAA	Examine procedural and interface design issues associated with the implementation of oceanic data-link communications.
Integrated Tools	AATT (747-400)	NASA Human Factors Division	Examine ATC/flight crew interactions in a distributed air-ground operation, in which both are equipped with advanced collision detection/resolution tools.
Taxiway Navigation and Situation Awareness (T-NASA)	TAP/LVLAO (ACFS)	NASA Human Factors Division	Increase safety and efficiency of aircraft landing and taxiing on the airport surface through integrating T-NASA and a Roll Out & Turn Off (ROTO) system.
Flight Procedure Standards	FAA (747-400)	FAA Aeronautical Center (Oklahoma City)	Examine operational issues associated with improving terminal area capacity and efficiency while maintaining or improving operational safety.
Fatigue Countermeasures	AOS (747-400)	NASA Human Factors Division	Investigate the effectiveness of an in-flight countermeasure to the fatiguing effects of long, overnight flights and techniques for measuring sleep/fatigue.
Multiple Parallel Approaches	FAA (747-400)	FAA Technical Center	Evaluate traffic handling capabilities and spacing requirements for running multiple simultaneous parallel approach operations.
Intelligent Neural Flight Controls	I.T. Base (ACFS)	NASA Computational Sciences Division	Evaluate neural net based intelligent flight control system as an adaptive flight control system capable of helping aircraft survive major system failures.
Roles and Responsibilities	AATT (747-400)	NASA Human Factors Division	Explore the determination of roles and responsibilities between the ground operators and pilots in the free flight environment.



Vertical Motion Simulator Research Facility

The Vertical Motion Simulator (VMS) complex is a world-class research and development facility that offers unparalleled capabilities for conducting some of the most exciting and challenging aeronautics and aerospace studies and experiments. The six-degree-of-freedom VMS, with its 60-foot vertical and 40-foot lateral motion capability, is the world's largest motion-base simulator. The large amplitude motion system of the VMS was designed to aid in research issues relating to controls, guidance, displays, automation, and handling qualities of existing or proposed aircraft. It is an excellent tool for investigating issues relevant to nap-of-the-earth flight and to landing and rollout studies.

Boeing B1, A1, A2

Henry Beaufre, Kurt Grevstad, Paul McDowell, The Boeing Company;
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Girish Chachad, Alberto Sanchez-Chew, Ron Gerdes, Logicon Syscon/Syre

Summary

During the Fiscal Year 1998, three separate VMS simulations were conducted to support the design and development of the Boeing X-32 Joint Strike Fighter and to advance NASA-sponsored research in guidance systems, display technology, and short takeoff/vertical landing controls.

Introduction

NASA Ames Research Center plays a key role in support of the U.S. Government's Joint Strike Fighter (JSF) Program, which will field an affordable, highly common family of next-generation, multi-role strike fighters for the Navy (USN), Air Force (USAF), Marine Corps (USMC), United Kingdom Royal Navy, and other U.S. allies. The military services have



The U.S. Navy variant of the JSF is shown performing a carrier landing.

stated their needs for the JSF as follows:

- USN - first-day-of-war survivable strike fighter aircraft to replace the A-6 and F-14 and to complement the F/A-18E/F
- USAF - multi-role aircraft (primary-air-to-ground) to replace the F-16 and A-10 and to complement the F-22
- USMC - short takeoff/vertical landing (STOVL) aircraft to replace the AV-8B and F/A-18A/C/D
- Royal Navy - STOVL aircraft to replace the Sea Harrier

The Boeing Company is one of two manufacturers selected to build and fly a pair of JSF concept demonstrator aircraft. Real-time, piloted flight simulation is an important step in Boeing's approach to JSF design and development. The VMS, with its large

motion travel, was used to complement Boeing's in-house, ground-based simulator prior to in-flight simulation and flight testing. The objectives of the three simulations included control law refinement, flying qualities evaluation, pilot-induced oscillation investigation, and advanced control and display design exploration.

Simulations

Test pilots from Boeing, USN, USAF, USMC, Royal Navy, Royal Air Force, and NASA participated in the evaluations. Simulations were conducted for a total of nine weeks on the motion base. In preparation for the motion-base experiments, a total of four weeks of fixed-base simulation was conducted to validate the simulation system response and to finalize flight tasks and scenarios. Validation of the response was critical because Boeing's entire aircraft simulation software was directly integrated into the VMS.

Results

The primary objectives of the simulations were met, and the customer obtained considerable information for design analysis and evaluation. Test pilots were favorably impressed with the important role that large motion cueing played in evaluating the JSF's flying qualities and mission capabilities. The competition sensitive nature of this project precludes the inclusion of detailed results in this report.

For SimLab, these simulations were the first to integrate the complete aircraft model software provided by the customer into the VMS simulation system. SimLab also created a visual database of the U.S. Navy's Patuxent River Test Center containing highly realistic aircraft carrier and tanker models for the JSF Program Office to support all JSF ground-based flight simulation activities. VMS personnel also developed head-up display graphics and lateral guidance logic for the simulation and incorporated specialized hardware for Boeing.

For information regarding the Boeing JSF program, please refer to <http://www.boeing.com>. For the U.S. JSF Program Office, see <http://www.jast.mil>.

Investigative Team

The Boeing Company
NASA Ames Research Center
U.S. Navy
U.S. Air Force
U.S. Marine Corps
U.K. Royal Navy
U.K. Royal Air Force

Simulation Fidelity Requirements 5

William Chung, Jeffery Schroeder, NASA ARC;
Soren LaForce, Norman Bengford, Logicon Syscon/Syre; Duc Tran, NASA ARC

Summary

Simulation Fidelity Requirements 5 utilized the large motion capabilities of the VMS to evaluate the effectiveness of simulator motion cues in predicting pilot-induced oscillation.

Introduction

In general, ground-based simulations have not accurately predicted pilot-induced oscillation (PIO). A previous study at Edwards Air Force Base documented PIO susceptibility using the NT-33 variable stability jet. The pitch control systems of the plane's flight control computer were arranged in 18 configurations, ranging in their susceptibility to PIO. The results of the Edwards study were used as a baseline for comparison in Simulation Fidelity Requirements 5 (SimFR 5).

The objective of SimFR 5 was to determine the effectiveness of various motion cueing levels in predicting PIO.

Simulation

A math model of the NT-33, including the 18 control system configurations tested in flight, was developed by NASA personnel. The offset landings originally flown at Edwards were chosen for their tendency to induce PIO and were simulated in SimFR 5 using an existing visual database of Edwards.

To study how effectively PIO is predicted with various levels of simulation motion cues, the 18 configurations were flown in three modes: large motion, small motion, and fixed-base. Large motion used the normal VMS range, small motion was limited to the range of a conventional hexapod platform, and fixed-base simulation involved no motion at all. For effective pitch cues, the cab was

oriented to allow 40 feet of longitudinal travel. Six test pilots from NASA Ames, Boeing, the FAA, and Logicon Syscon/Syre completed a total of 1720 data runs.

Results

Initial results indicate that large motion best matched the in-flight results for handling qualities and PIO ratings. Only with large motion did significant PIO occur, probably due to the pilots' reactions to the high-fidelity vertical acceleration cues. With large motion, pilots assigned higher confidence factor ratings, achieved lower touchdown velocities, and caused fewer safety pilot trips as compared to the other motion configurations. Results of the study were presented to the 1998 Atmospheric Flight Mechanics Conference of the American Institute of Aeronautics and Astronautics in the paper "Pilot-Induced Oscillation Prediction with Three Levels of Simulation Motion Displacement."

Investigative Team

NASA Ames Research Center
Logicon Syscon/Syre
The Boeing Company
Federal Aviation Administration



The NT-33, an in-flight simulator with a programmable flight control system, provided the baseline data for this study of simulator motion cues.

Civil Tiltrotor 7

William Decker, NASA ARC;

Steve Belsley, Emily Lewis, Philip Tung, Norman Bengford, Logicon Syscon/Syre

Summary

Continuing a series of tiltrotor simulations at the VMS, Civil Tiltrotor 7 investigated aircraft guidance, terminal flight procedures, and varying environmental conditions for tiltrotor transports. Flight path vector guidance with a longitudinal control director was implemented, and the effects of tail winds on approach profiles were evaluated.

Introduction

Civil Tiltrotor 7 (CTR 7) was the latest in a series of simulations to investigate issues that include CTR certification, terminal area operations, and vertiport design. Recent experiments have investigated power level requirements for one-engine-inoperative operations and noise abatement procedures for vertiports located in congested areas. Implementing noise abatement procedures and maneuvering in airport terminal airspace require complex instrument approaches. Previous simulations have highlighted the need for appropriate guidance for these approaches, during which conversion from airplane mode to helicopter mode occurs. In CTR 6, lateral flight path guidance was evaluated.

CTR 7 was designed to examine aircraft guidance, terminal flight procedures, and environmental conditions. Specific objectives included the implementation of the flight path vector guidance with a longitudinal control director, the evaluation of tail wind effects on approach profiles based on ground speed, and the evaluation of a new wind model that includes an

earth boundary layer and directional shear effects. For control design and analysis, CTR 7 documented aircraft speed, rotor speed, and thrust control response. Members of the FAA's Vertiport Design Guide Working Group were invited to the VMS to observe design and tiltrotor operation issues.

Simulation

The simulation marked the first CTR use of the TCAB. This new cab was designed for the simulation of civil transport aircraft and features two side-by-side seats, a full range of electronic instruments, and a 240° X 60° field of view. Flight procedures for CTR 7 were therefore modified to include the duties of a second, non-flying pilot. For more effective acceleration and deceleration motion cueing during the critical nacelle conversion, the TCAB was oriented to allow 40 feet of longitudinal travel. The use of a side-stick controller for CTR was introduced in this simulation. Test pilots from the FAA, NASA, and industry participated in the experiment. Experienced in-house pilots evaluated the side-stick controller and the new wind shear model.

Results

CTR 7 successfully implemented flight path vector guidance with a longitudinal control director. Information was documented for aircraft speed, rotor speed, and thrust control response for control system analysis and design. With the introduction of the two-seat TCAB to CTR simulations, a second pilot was integrated into the CTR scenario, and duties were defined for the non-flying pilot. The new wind model and the effects of tail winds on approach profiles were evaluated. Vertiport design and tiltrotor operation issues were demonstrated to members of the Vertiport Design Guide Working Group.

Investigative Team

NASA Ames Research Center
Logicon Syscon/Syre
Bell Helicopters
The Boeing Company
Sikorsky Aircraft
Federal Aviation Administration
U.S. Army



CTR 7 introduced a second pilot to Civil Tiltrotor simulations with the TCAB. Pictured is the pilot's station with CTR displays.

Lockheed Martin

Mark Tibbs, Lockheed Martin; James Franklin, NASA ARC;
Robert Morrison, Leslie Ringo, Joe Oggwell, Luong Nguyen, Ernie Inn, Logicon Syscon/Syre

Summary

Lockheed Martin's X-35 Joint Strike Fighter model was simulated to support the design and development of the X-35 and to advance NASA-sponsored research in guidance systems, display technology, and short takeoff/vertical landing controls.

Introduction

NASA Ames Research Center plays a key role in support of the U.S. Government's Joint Strike Fighter (JSF) Program, which will field an affordable, highly common family of next-generation, multi-role strike fighters for the Navy (USN), Air Force (USAF), Marine Corps (USMC), United Kingdom Royal Navy, and other U.S. allies. Each of the military services has specified unique requirements for its version of the JSF. For example, the USAF primarily expects an air-to-ground fighter that will be a significant improvement over the F-16. The USN variant will serve as a strike fighter to replace the A-6 and F-14. The USMC version distinguishes itself with its short takeoff/vertical landing capabilities and will serve as a replacement for the AV-8B and F/A-18A/C/D. The JSF is expected to enter service in 2008.

The Department of Defense awarded Lockheed Martin Corporation one of two JSF contracts. The contract calls for two concept demonstrator aircraft, the first of which is scheduled for rollout in 1999. This simulation, using the large motion base at the VMS, was conducted by Lockheed Martin to complement their in-house simulations as part of the design and development process. The objective of the experiment included control law refinement, flying qualities evaluation, and advanced control and display design exploration.

Simulation

Two weeks of fixed-base simulation were followed by three weeks of motion-base operations. The fixed-base session was designed to validate the simulation system response and to finalize flight tasks and scenarios in preparation for the motion-base experiment. The response validation phase was a critical step since the computer code for the entire aircraft model was generated by Lockheed Martin and directly integrated into SimLab's simulation environment. Pilots and engineers from Lockheed Martin, the U.S. Navy and Marine Corps, U.K. Royal Air Force and Royal Navy, and British Aerospace participated in the evaluations.

Results

The primary objectives for the simulations were met, and significant amounts of evaluation data were collected. The large motion cueing of the VMS system played a critical role in evaluating the flying qualities and mission capabilities of Lockheed Martin's JSF design.

For SimLab, this simulation marked a continued success in integrating the entire aircraft model software provided by a customer into SimLab's real-time system. This mode of operation allowed Lockheed Martin to test several last minute design changes, which were expediently integrated by SimLab engineers. Due to the competition sensitive nature of the project, detailed results cannot be included in this report.

For further information regarding the JSF program, please refer to the Lockheed Martin and JSF Program Office world wide web pages at <http://www.lmco.com> and <http://www.jast.mil>, respectively.

Investigative Team

NASA Ames Research Center
Lockheed Martin
U.S. Marine Corps
U.K. Royal Navy
U.K. Royal Air Force
British Aerospace



The Joint Strike Fighter is an advanced tactical multirole aircraft concept developed for the U.S. Air Force, Navy, Marine Corps, and British Royal Navy. The JSF features stealthy design, high maneuverability, and affordability.

Space Shuttle Vehicle 1

Howard Law, NASA JSC; Kyle Cason, The Boeing Company; Jim Harder, United Space Alliance; Estela Hernandez, Christopher Sweeney, Logicon Syscon/Syre

Summary

The Space Shuttle Orbiter landing and rollout studies are performed at the VMS to fine-tune the Orbiter's landing systems. The primary goal of this simulation was to study the effects of changing the flow rate of the hydraulic system powered by the Auxiliary Power Unit.

Introduction

The Space Shuttle Orbiter has been simulated at SimLab since the late 1970s. The simulation at Ames has been used to test flight control improvements, safety features, head-up display developments, proposed flight rule modifications, and changes to the basic simulation model, which has evolved over the years. The simulation is also used to train astronauts with realistic landing and rollout scenarios before their flight and includes scenarios with system failures.

Simulation

Simulation objectives were to:

- Study the effects and pilot procedures of single and dual Auxiliary Power Unit (APU) failures during approach and landing. This was studied primarily due



Twice yearly, the Space Shuttle Orbiter is simulated for landing and rollout engineering studies.

to a recent SSV mission in which a single APU failure occurred.

- Study the effects of increasing the flow rate of a single or dual APU hydraulic system from 63 gallons per minute to 90 gallons per minute per APU. The proposed increase would be coupled with changes to the Priority Rate Limiting system.
- Continue evaluation of Virtual Laboratory (VLAB). VLAB allowed researchers at Johnson Space Center to monitor and interact with Shuttle simulations in progress at the VMS and to record data. (For more on VLAB, see the Technology Upgrades section page 44.)
- Train upcoming mission crews and astronaut candidates through a crew familiarization matrix.

For this simulation, the gear model was modified to simulate tire deflection, and the capability to immediately display APU data at the end of each run was added. A program was written to automatically translate the Space Shuttle Vehicle test matrix into data files for input into the simulation program. The program eliminated several days of manual entry to a several hour process and can be adapted for other simulations.

Results

A total of 1210 runs was completed with 35 pilots. Preliminary results show that for the 63 gallons per minute single or dual APU, landings can be successfully achieved if the pilot avoids control surface saturation by minimizing control inputs. Preliminary results also show that the increased flow rate to 90 gallons per minute, coupled with changes to the Priority Rate Limiting logic, would reduce the frequency and duration of rate saturation.

The crew familiarization phase of the simulation reinforced the importance of the VMS in preparing upcoming crews for the landing and rollout phase of the mission and for possible failures during that phase.

Investigative Team

NASA Johnson Space Center
NASA Ames Research Center
The Boeing Company
United Space Alliance

Helicopter Maneuver Envelope Enhancement 5

Matthew Whalley, Jay Shively, U.S. Army AFDD;
Chuck Perry, Alberto Sanchez-Chew, Logicon Syscon/Syre

Summary

The latest in a series of VMS simulations, this experiment continued research into predicting helicopter flight envelope limits and communicating those limits to the pilot. In this simulation, tactile cueing of blade stall and mast bending moment were implemented using polynomial neural networks.

Introduction

Helicopters typically have complicated flight envelope limits that are difficult to predict during flight and that are poorly displayed to the pilot. To date, only indirect and simplified cueing of limits has been viable. The introduction of fly-by-wire (all-electronic) control systems has further decreased pilot awareness of control actuator authority limits and has eliminated flight control force feel. Consequently, conservative restrictions to the maneuvering envelope are often imposed.



HelMEE 5 simulated the UH-60 Black Hawk with a standard flight control system.

The purpose of the Helicopter Maneuver Envelope Enhancement (HelMEE) simulation series is to increase pilot awareness of envelope limits. HelMEE 4 implemented a polynomial neural network (PNN) to predict transmission torque limits and a control force feel system to provide tactile cueing of those limits to the pilot. Force cues were delivered through the collective and indicated when the transmission torque output relative to a maximum continuous limit was reached.

HelMEE 5 continued this investigation of cueing using PNNs. The goals of the simulation were to improve the PNN used in HelMEE 4, to implement collective cueing for blade stall, and to implement cyclic cueing for mast bending moment.

Simulation

HelMEE 5 simulated the UH-60 Black Hawk with a standard flight control system. Considerable effort was devoted to improving the PNN performance. Additional test parameters, such as high altitudes, high ambient temperatures, and high aircraft gross weight were simulated to increase torque and mast bending moment, requiring the helicopter to operate near its limits more frequently. The collective and cyclic cues were exercised both separately and together.

Collective cueing for both torque and blade stall was achieved by implementing a softstop and a high gradient force. The softstop allowed the pilot to pull through the cue if desired. Because mast bending moment is more dependent on the velocity of stick input than on the stick position, cyclic cueing was introduced as a large increase in the damping force. In all cases, stick shaking and head-up displays were used as additional limiting cues.

Results

The results of HelMEE 5 indicate improved pilot task performance and reduced pilot workload. Effective cueing reduced or eliminated the need to visually monitor the torque gauge during a task. A significant improvement was found in the handling qualities ratings provided by the test pilots. In all, 872 runs, including 387 data runs, were flown by pilots from NASA, Logicon Syscon/Syre, FAA, Boeing Helicopters, Bell Helicopters, Columbia Helicopters, and three U.S. Army organizations.

Investigative Team

U.S. Army
NASA Ames Research Center
Logicon Syscon/Syre
Boeing Helicopters
Bell Helicopters
Columbia Helicopters
Federal Aviation Administration
Barron Associates

Slung Load 5

Chris Blanken, U.S. Army AFDD; Robert Heffley, R. Heffley Engineering;
Roger Hoh, Hoh Aeronautics; Robert Morrison, Logicon Syscon/Syre

Summary

The CH-47D Chinook helicopter was simulated to improve handling qualities criteria for cargo helicopters in slung load operations and to refine techniques for measuring those criteria.

Introduction

The Slung Load 5 simulation experiment, the fifth in a series of VMS simulations conducted by the U.S. Army Aeroflightdynamics Directorate, was performed to obtain data for specifying handling qualities for cargo helicopters in slung load operations. This research is part of the Army's Improved Cargo Helicopter program, aimed at upgrading the Boeing CH-47D Chinook heavy-cargo helicopters to extend their lives beyond the year 2020. Without the program, the first Chinooks would reach the end of their service life in 2002. A secondary aim of the simulation was to correct deficiencies in the CH-47Ds that adversely affected their mission operations during Desert Storm.



Pictured above is a view of the simulator cockpit configured for the Slung Load simulation.

Data from prior Slung Load simulations raised several questions and issues. While many useful handling qualities criteria have been defined for cargo helicopter operations with slung loads, a few inconsistencies in the data indicate that the understanding of how to apply the proposed standards is incomplete. Other lingering questions concerned measurement techniques for handling qualities

characteristics, particularly for frequency response definition.

The purpose of the Slung Load 5 experiment was to resolve these questions and issues by reviewing configurations that are inconsistent with currently proposed criteria, studying the measurement of handling qualities features in more depth, and exploring previously unexamined frequency response features.

Specifically, the objectives included: studying the validity of gain margin handling qualities criteria for slung load tasks (mainly precision hover), providing a better theoretical basis for bandwidth criteria by defining the load-off rating trend for precision hover with the load-on performance time, gathering data on how ratings are influenced by the large difference in moments of inertia in the roll and pitch axes, and continuing the study of frequency response measurement methods using pilot-produced inputs.

Simulation

The CH-47D was simulated with various configurations: with and without a slung load of 16,000 pounds, with single- and dual-point suspended loads, with loads using various sling lengths and distances from the hook to the aircraft center of gravity, and with different control system gains. With the slung load, the dynamics of the aircraft are affected not only by the basic aircraft response but also by the coupled response from the external load. Pilots from NASA, Boeing, and Logicon/Syre flew a total of 885 data runs.

Results

Slung Load 5 developed important handling qualities relationships for a large variety of control systems and sling configurations. For internal loads, the bandwidth parameter was determined to be a good control response discriminator but was found to be insufficient by itself for characterizing the control response with external loads. Finally, the large motion provided by the VMS proved essential in providing the pilot with realistic cues of the motion caused by the swinging of the external load.

Investigative Team

U.S. Army
NASA Ames Research Center
The Boeing Company
Logicon Syscon/Syre
R. Heffley Engineering
Hoh Aeronautics

Simulation Fidelity Requirements 6

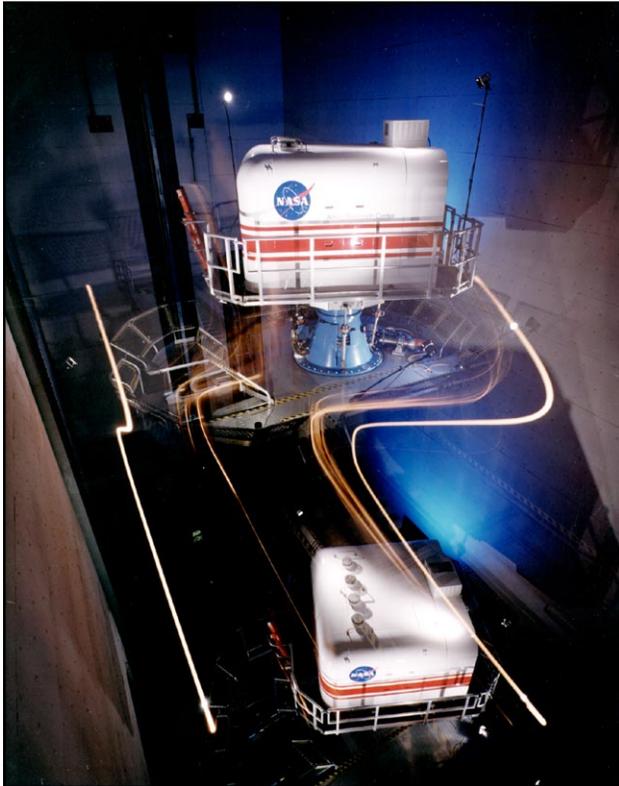
William Chung, Logicon Syscon/Syre; Jeffery Schroeder,
Duc Tran, NASA ARC; Ron Hess, UC Davis; Soren LaForce, Logicon Syscon/Syre

Summary

Simulation Fidelity Requirements 6 was a joint research program with the University of California at Davis that used the large vertical travel of the Vertical Motion Simulator to gather data for the development and validation of a pilot model.

Introduction

Visual and motion cues play a critical part in piloted simulation and significantly affect a pilot's perception of vehicle response, which in turn affects a pilot's performance of defined tasks. Exactly how these cues affect the pilot and to what degree are yet to be determined in a validated scientific study. Each cue has numerous characteristics or attributes; for example, scene content, resolution, and field of view



Simulation Fidelity Requirements 6 was a joint research program with the University of California at Davis that used the large vertical travel of the Vertical Motion Simulator to gather data for the development and validation of a pilot model.

are just some of the characteristics of the visual cue. These attributes directly affect pilot perception and interactively produce significant changes in pilot response.

The objective of Simulation Fidelity Requirements 6 (SimFR 6) was to develop and validate a pilot model in a single degree of freedom to characterize how the pilot processes and responds to major visual and motion cueing attributes. Development of a validated pilot model will provide important objective insight and will advance the development of standards and criteria for cueing fidelity in ground-based flight simulation.

Simulation

To begin this line of inquiry, SimFR 6 limited the scope of the study to the vertical motion axis and to select characteristics. Three cueing attributes were chosen: visual resolution, field of view, and magnitude of motion. The experiment combined these cues in 42 configurations. A one-to-one motion cueing configuration, in which the simulator exactly duplicated aircraft response, was developed as a baseline case. A precision hover task with a 40-foot bob-up and bob-down was flown. Particular care was taken to ensure the synchronous delivery of motion and visual cues.

Results

SimFR 6 was successful in the collection of data regarding the effects of various cueing configurations. A total of 1068 data runs were recorded. The data will be used to develop and validate a pilot cueing perception model in the vertical axis. After validation, the methodology of this investigation will be expanded to multiple degrees of freedom, contributing to the development of standards and criteria that will help determine minimum requirements for cueing in motion-base simulation.

Investigative Team

NASA Ames Research Center
Logicon Syscon/Syre
UC Davis
U.S. Army

High Speed Civil Transport Design & Integration

Thea Feyereisen, Bill Rogers, Honeywell; Gordon Hardy, Logicon Syscon/Syre;
Christopher Sweeney, Joseph Ogwell, Robert Morrison, Phil Tung, Logicon Syscon/Syre;
Duc Tran, NASA ARC

Summary

This study, conducted by the Design and Integration team of the High Speed Research Program, examined two areas of flight deck management: Crew Interaction with Automation and Crew/Autoflight Integration.

Introduction

The High Speed Research (HSR) Program is a collaborative effort between NASA and the U.S. aeronautics industry. The goal of this effort is to develop the high-leverage technologies necessary for an environmentally acceptable, economically viable high speed civil transport (HSCT) and to provide intercontinental service at Mach 2.4 for three hundred passengers beginning in the year 2005.

In support of this goal, the HSR Program's Design and Integration team has developed various con-



A series of simulations and flight tests is designed to validate guidelines and methods to meet the flying qualities and certification criteria for an HSCT development program.

cepts for flight deck management. HSR Program milestones called for final piloted evaluation of the concepts in a simulator.

Simulation

High Speed Civil Transport Design and Integration (HSCT D&I) evaluated flight deck design concepts in terms of pilot performance, workload, and situation awareness in managing and interacting with several different automated systems unique to the HSCT. The systems were divided into two areas of study.

1. Crew Interaction with Automation - High-lift devices on the HSCT have dynamic schedules rather

than the discrete static schedules typical on subsonic aircraft; hence, a discrete setting flap lever would be inadequate, and control of the schedules will likely be highly automated under normal circumstances. The pilots need to stay involved in and informed about high-lift device authority and status in order to detect anomalies and revert to a less automated level of control if necessary. The automated flap control is anticipated to make manual control of thrust more difficult. Evaluation of pilot performance while interacting with the high-lift device automation and manual throttles in normal and failure modes were goals of the Crew Interaction with Automation study.

2. Crew/Autoflight Integration - The HSCT will have different control laws than normal aircraft, changing the requirements and interface issues for aircraft mode control and annunciation. An autoflight mode structure must be developed that is understandable and consistent with the flight control law paradigms. The effect of this structure on envelope protection, mode awareness, and pilot procedures must be addressed. Pilot performance and awareness while interacting with and monitoring the autoflight system were the key goals of the Crew/Autoflight Integration portion of the experiment.

The bare airframe model was updated to the latest HSCT design release for HSCT D&I. The control laws were implemented using Matlab Simulink design tools. Matlab's autocoding feature was used to convert the block diagrams into C language routines, which were integrated with the rest of the FORTRAN code. Algorithms for a Mode Control Panel and vertical guidance logic were also added to the model.

Results

For HSCT D&I, 105 data runs of three different tasks were completed for the two areas of study. Preliminary results indicate that pilot awareness of the unique problems of an HSCT aircraft is critical and that advanced flight deck management concepts will need further development.

Investigative Team

The Boeing Company
Honeywell
NASA Ames Research Center
NASA Langley Research Center
Logicon Syscon/Syre

High Speed Civil Transport A7

Jim Ray, Todd Williams, The Boeing Company; Gordon Hardy, Logicon Syscon/Syre;
Christopher Sweeney, Joseph Ogwell, Robert Morrison, Phil Tung, Logicon Syscon/Syre

Summary

The High Speed Research Program conducted a four-part experiment in the VMS to evaluate the performance of the flight control system and to verify and validate the bending mode response of the high speed civil transport.

Introduction

To support the development of a high speed civil transport (HSCT), the High Speed Research (HSR) Program's Guidance and Flight Controls team is conducting a series of simulations and flight tests designed to validate guidelines and methods to meet flying qualities and certification criteria. (For more on the HSR Program, see the HSCT D&I Introduction on page 24.)

Simulation

Part 1, the main thrust of High Speed Civil Transport Ames 7 (HSCT A7), involved gathering handling quality ratings (HQRs) for the entire flight envelope to determine if the control system designs have met targeted HQRs. Forty-one flight cards were used to gather data on takeoff, approach and landing, cruise, envelope protection, and failure tasks. Each card had a target HQR, and a database of pilot opinion and performance was generated to evaluate the vehicle and control laws against these targets.

Part 2 of the study attempted to discover appropriate levels of roll control sensitivity criteria (roll acceleration per pound force of lateral stick) in order to develop a criterion for the flying qualities level 1-2 boundary of an HSCT type aircraft in both subsonic and supersonic flight regimes. For Part 3, a modified HSCT configuration was evaluated for improvements in the approach and landing phase of flight. For Part 4, an initial attempt was made to evaluate the effects of the bending modes, or the Dynamic Aero Servo Elastic (DASE) response of the aircraft, on the pilot and control laws.

Dynamic Aero Servo Elastics (DASE) is the phenomenon which results from the interaction between aerodynamic forces, structural (elastic) forces, and inertial forces. DASE excites the natural bending modes of the aircraft, causing the aircraft to vibrate. If left uncontrolled, these vibrations can affect

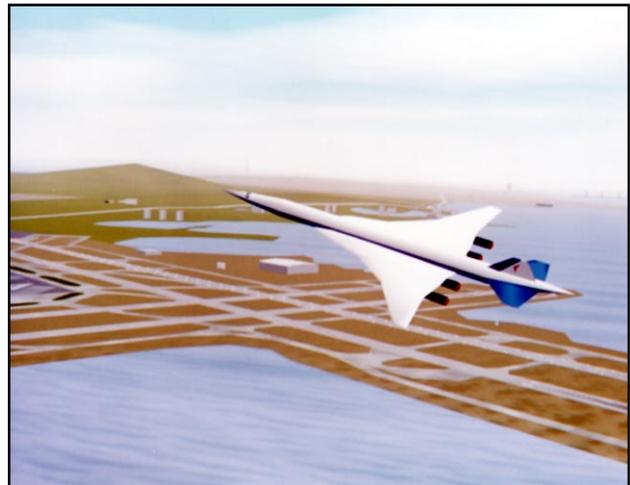
the comfort and safety of passengers, as well as the structural integrity of the aircraft. Therefore, it is critical that the DASE effects be investigated for this aircraft, which has a unique shape and will operate over a wide range of speeds.

Simulation Results

Preliminary results for the simulation indicate that the Guidance and Flight Control design element is exceeding desired HQR targets for most of the flight envelope; only a few areas of the envelope need refinement. A large quantity of data was gathered to help designers determine the appropriate roll control sensitivity. The modified HSCT configuration performed well in the approach and landing task, but might be unnecessary since Level 1 HQRs were achieved with the baseline configuration. The evaluation of the bending mode effects proved to be a beneficial first look, which revealed the relevant issues that warrant further investigation.

Investigative Team

The Boeing Company
Honeywell
NASA Ames Research Center
NASA Langley Research Center
Logicon Syscon/Syre



The goal is to develop the high-leverage technologies necessary for an environmentally acceptable, economically viable High Speed Civil Transport.

High Speed Civil Transport A7B

Dennis Henderson, Payam Rowhani, The Boeing Company; Gordon Hardy, Logicon Syscon/Syre; Christopher Sweeney, Joseph Ogwell, Phil Tung, Logicon Syscon/Syre

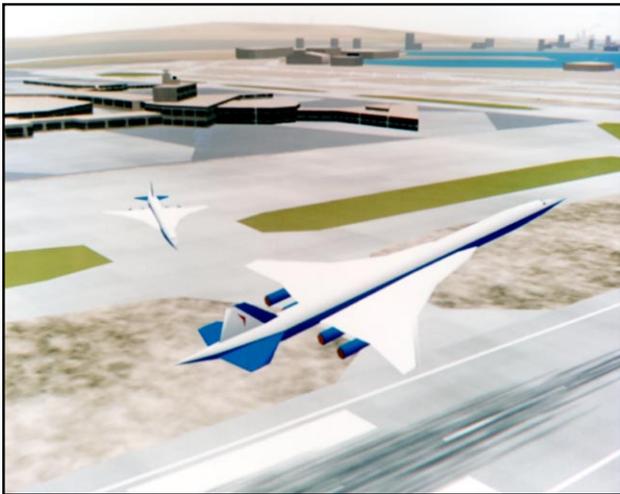
Summary

This experiment was conducted by the High Speed Research Program to evaluate the modeling of the Dynamic Aero Servo Elastic effects and the aircraft response during approach and landing.

Introduction

To support the development of a high speed civil transport (HSCT), the High Speed Research (HSR) Program's Guidance and Flight Controls team is conducting a series of simulations and flight tests designed to validate guidelines and methods to meet flying qualities and certification criteria. (For more on the HSR Program, see the HSCT D&I Introduction.)

During the earlier High Speed Civil Transport Ames 7 (HSCT A7) simulation, the Dynamic Aero Servo Elastic (DASE) model was added to the nominal HSCT aircraft in the last week of the simulation. (For more on DASE, see HSCT A7 on page 25.) Many issues were identified for further investigation in a follow-on experiment. In HSCT A7B, the aircraft's twenty bending modes were predicted to make the piloting task a difficult one without any active structural mode control (SMC). This study evaluated the accuracy of the DASE modeling; the effectiveness of the SMC; the ability of the VMS motion system to accurately reproduce the pilot station accelerations; and the effects of inceptors, center stick versus



In High Speed Civil Transport A7B, an alternate method of implementing the Dynamic Aero Servo Elastic model was investigated.

wheel/column, on the tendency of the pilot to bio-couple with the aircraft.

Simulation

In HSCT A7B, an alternate method of implementing the DASE model was investigated. In order to run the entire simulation at 100 Hz (HSCT A7 sub-framed the DASE model at 400 Hz), only the first seven bending modes (up to 20 radians per second) were used.

Two different methods of control law implementation were tested. The continuous model of the control law contained a cascade of filters, to which the Matlab autocoder added a cycle of delay for each filter. A discretized version of the control law tuned for 100 Hz was developed to remove this known programming delay. However, the lateral-directional portion of this control law implementation was found to be unstable; therefore, most of the data for the simulation was taken with the continuous control law implementation.

Simulation Results

Closed loop (with the control laws) piloted runs were made with and without SMC and with the center stick and wheel/column by three pilots. All of the pilots agreed that the DASE aircraft with SMC off was a Level 3 vehicle. Two of the pilots had some degree of bio-coupling with the center stick, while the only pilot who flew with the wheel/column did not experience such problems. The SMC improved the vehicle handling qualities ratings to Level 1/Level 2. Further investigation is needed with the VMS motion system tuned to provide the highest possible motion fidelity to simulate the high-frequency effects of the DASE characteristics.

Investigative Team

The Boeing Company
NASA Ames Research Center
NASA Langley Research Center
Logicon Syscon/Syre

Partial Authority Flight Control Augmentation

Matthew Whalley, U.S. Army AFDD; Jeremy Howitt, U.K. DERA;
Chuck Perry, Emily Lewis, Logicon Syscon/Syre

Summary

This simulation investigated the flying qualities improvement potential of a Partial-Authority Flight Control System. An enhanced attitude command/attitude hold control system was implemented in a UH-60 Black Hawk model for pilot evaluation.

Introduction

Full-authority fly-by-wire (FBW) active control technology (ACT) can provide aircraft with optimum flying qualities. However, implementing full-authority ACT in current in-service helicopters is a relatively high-risk, high-cost option. For this reason, a system is desired that augments conventional full-authority mechanical control with a limited-authority automatic flight control system (AFCS). Partial-Authority Flight Control Augmentation (PAFCA) is being investigated to determine its potential to improve flying qualities by providing a functionality similar to a full-authority FBW system using only limited-authority actuation technology.

A previous PAFCA simulation, performed by the United Kingdom's Defense Evaluation and Research Agency, suggested that if the augmented response characteristics are properly designed, series actuator saturation does not degrade handling qualities, even if significant periods of saturation take place.

The goals of this investigation were to verify that matching the frequency response of the open and closed loop dynamics of the vehicle results in acceptable handling qualities in and around the region of



This simulation studied AFCS saturation maneuvers under degraded visual conditions, that is, under night operations with night vision goggles.



Out-the-window view as seen through the night vision goggles.

stability and control augmentation system (SCAS) saturation. Specifically, the objectives were:

- To implement an attitude command/attitude hold (ACAH) response type within the constraints of a PAFCA Black Hawk architecture. Two ACAH controller gainsets were synthesized: a frequency-matched set and a performance-matched set.
- To investigate the impact of AFCS saturation on handling qualities in hover and low-speed maneuvers under degraded visual conditions, that is, under night operations with night vision goggles, as compared to a standard Black Hawk configuration with rate command/attitude hold (RCAH).
- To investigate series actuator authority limits of 10%, 15%, and 50%, as compared to the standard Black Hawk limit of 10%.
- To obtain design data that can be used for potential Black Hawk in-service control system upgrades.

Results

- Simulation goals were met. Nine pilots flew 1422 evaluation runs, and these highlights were noted :
- An ACAH response type was preferred to the standard Black Hawk RCAH response type for degraded visual environment operations.
 - Frequency-matching SCAS was preferred over performance-matching SCAS.
 - The 15% level of series actuator authority was preferred, probably due to decreased pilot workload.

Investigative Team

U.S. Army
U.K. DERA
NASA Ames Research Center
Logicon Syscon/Syre

Space Shuttle Vehicle 2

Howard Law, NASA JSC;

Estela Hernandez, Leslie Ringo, Christopher Sweeney, Logicon Syscon/Syre

Summary

Simulations of the Space Shuttle Orbiter are generally performed at the VMS to conduct landing and rollout engineering studies and to provide crew training. This simulation was devoted entirely to training crews of upcoming missions and astronaut candidates. The simulation also continued the evaluation of Virtual Laboratory as a remote-access simulation tool.

Introduction

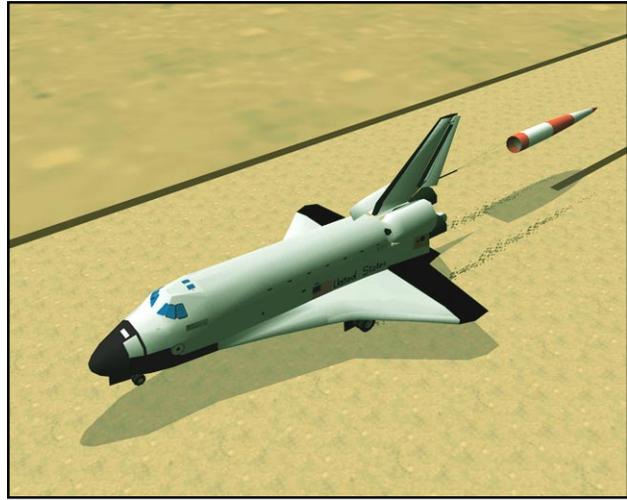
The Space Shuttle Orbiter has been simulated at the VMS since the late 1970s. The simulation model has evolved over the years and is updated to reflect modifications to the Shuttle. With its superior motion cueing, the VMS provides excellent training opportunities for Shuttle crews.

Virtual Laboratory (VLAB), a virtual reality environment that enables researchers at remote sites to monitor and interact with experiments at the VMS, was deployed to Johnson Space Center (JSC) for this simulation. (For more on VLAB, see the Technology Upgrades section on page 44.)

Simulation

Training procedures consisted of each pilot landing the Space Shuttle Orbiter with various configurations, initial conditions, and failure modes, based on cases defined in the crew-familiarization matrix. Simulation variables included wind direction and speed, chute deployment speed, visibility (day or night, clear or cloudy), and location and type of runway (concrete or lakebed). U.S. runways that were simulated included Kennedy Space Center (KSC) 15, KSC 33, Edwards 15, Edwards 22, Edwards 23, Northrop White Sands lakebed, Palmdale, and Vandenberg. Transatlantic landing sites were located in Africa (Banjul, Ben Guerir and Dakar) and Spain (Moron and Zaragoza). Periodically, engineers introduced failures to the tires, to a single Auxiliary Power Unit, to the Microwave Landing System, and to beep trim.

In August 1998, two VMS simulation engineers observed the training of Shuttle crews aboard the Shuttle Training Aircraft, an in-flight simulator. This valuable firsthand experience exposed the engineers to actual cockpit hardware and to crew training procedures during landings at Northrop runways at White Sands, New Mexico. The orientation flights also helped to identify areas for possible improve-



During Shuttle simulations, failure modes are tested, such as this simulation of a parachute failure.

ments to VMS simulations.

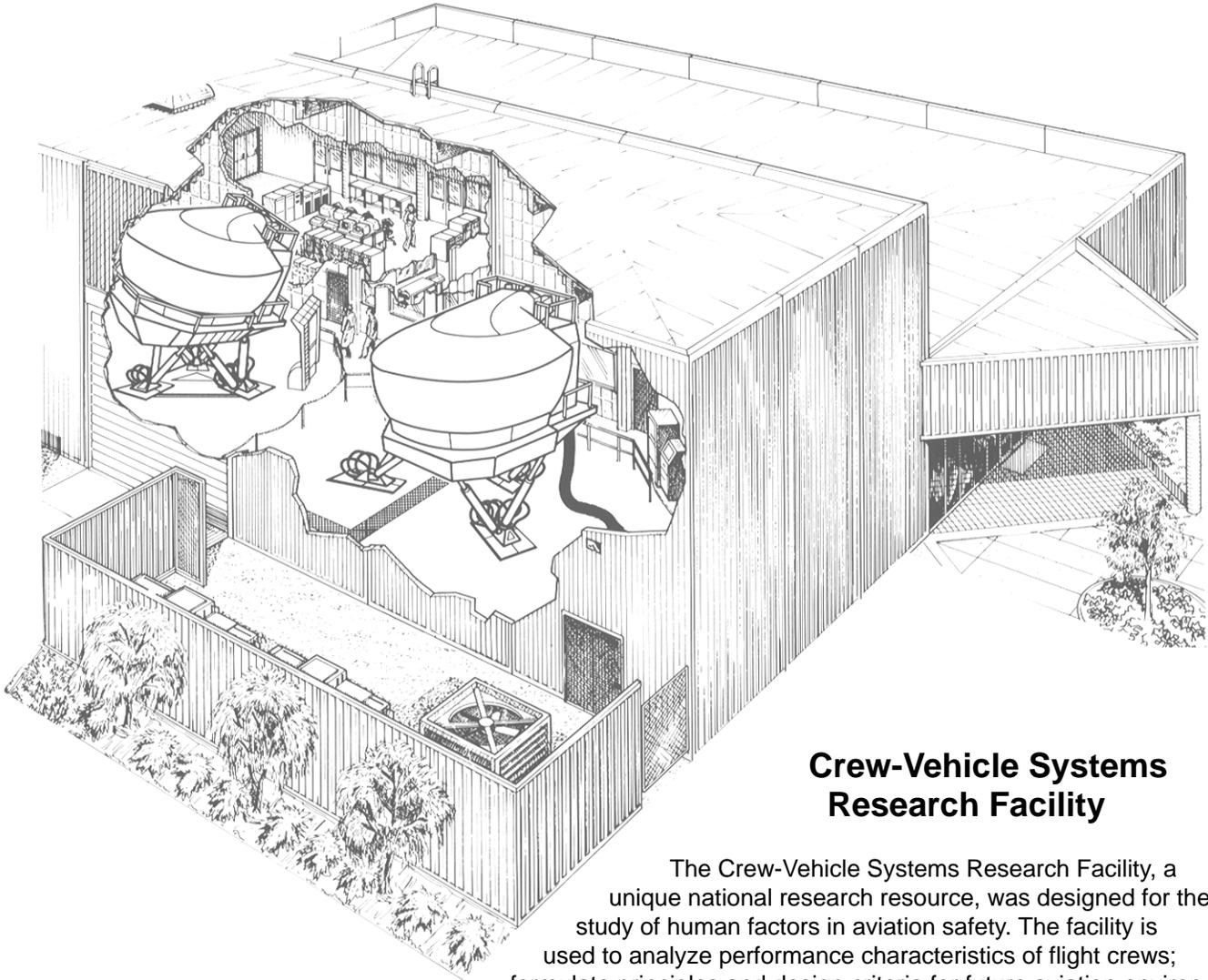
Results

Thirty-five pilots flew over 682 data runs to accomplish the crew familiarization objective. Participating were crews from several upcoming missions, including STS-88, 92, 93, 95, 96, 97 and 98. Astronaut candidates also took part in the training. In addition, former astronauts from the Shuttle Program Office, including John Young, participated. VLAB proved successful in allowing researchers at JSC to interact with the simulations as they occurred. This simulation reinforced the importance of the VMS in preparing upcoming crews for the landing and rollout phase of the mission and for possible failures during that phase.

Investigative Team

NASA Johnson Space Center
NASA Ames Research Center
The Boeing Company
United Space Alliance





Crew-Vehicle Systems Research Facility

The Crew-Vehicle Systems Research Facility, a unique national research resource, was designed for the study of human factors in aviation safety. The facility is used to analyze performance characteristics of flight crews; formulate principles and design criteria for future aviation environments; evaluate new and contemporary air traffic control procedures; and develop new training and simulation techniques required by the continued technical evolution of flight systems.

Studies have shown that human error plays a part in 60 to 80 percent of all aviation accidents. The Crew-Vehicle Systems Research Facility allows scientists to study how errors are made, as well as the effects of automation, advanced instrumentation, and other factors, such as fatigue, on human performance in aircraft. The facility includes two flight simulators - a Boeing 747-400 and an Advanced Concepts Flight Simulator as well as a simulated Air Traffic Control System. Both flight simulators are capable of full-mission simulation.

Decision Making

Judith Orasanu, NASA ARC; Jeanie Davison, Laura Tyzzer, Eric Villeda, Lori McDonnell, Christina Van Aken, SJSU; Jerry Jones, Rod Ketchum, Diane Carpenter, NSI Technology Services Corp.

Summary

The 747-400 simulator was used to determine the factors that influence pilots' success in monitoring and detecting problems in flight and to investigate communication strategies used to call attention to or correct those problems. The study took into account factors such as the relative rank of the crew members, the type of problem, and the level of risk.

Introduction

In a 1994 analysis of accidents caused by flight crews, the National Transportation Safety Board found that 31 of 37 accidents involved failures of monitoring and challenging by a crew member who was not flying at the time. In these cases, the crew member was unable to get the attention of the pilot flying or was unable to persuade the other pilot to take action. The problems arose either from the flying pilot's error or from an external source, such as other traffic, air traffic control, or weather conditions. In most incidents, it was the first officer who attempted to persuade the captain to take action. Little research has been conducted to establish which factors determine when crew members notice problems and

decide to intervene and which intervention strategies are successful.

The Aviation Safety Research Branch of NASA's Flight Management and Human Factors Division undertook this study to assess the influences of certain factors on communication and to investigate which intervention strategies contribute to success.

Simulation

In each run, a retired 747-400 captain, who was a confederate, acted as the flying pilot and assumed the rank of captain for some runs and the rank of first officer for others. The confederate pilot either committed a scripted error or compounded an existing problem. Flight scenarios developed for the study differed in the level of risk that existed and in the degree to which the flying pilot was responsible for the problem or error. The verbal response to the problem or error by the non-flying crew member was the dependent measure. The time for the pilot to respond after cues signaling a problem had been presented was also analyzed.

Results

Results of this simulation were examined in light of three variables: the relative rank of the crew members, the type of problem, and the level of risk. Participating in the study were 11 captains and 11 first officers. Each day's runs consisted of five different line-oriented flight scenarios. Preliminary findings suggest that participating captains did not perceive the events that took place in the study to be as risky as perceived by the participating first officers when faced with the same situations.

Contributing factors will be evaluated, and procedural recommendations will be considered by the Aviation Safety Research Branch.

Investigative Team

NASA Ames Research Center
San Jose State University



This study examined flight crew communications in both low- and high-risk situations and how these risks affected pilot decision making.

Propulsion Controlled Aircraft 3

Joseph Totah, NASA ARC; John Bull, CAELUM Research Corp.;
Diane Carpenter, Jerry Jones, NSI Technology Services Corp.

Summary

The 747-400 simulator was used to examine a low-cost, fly-by-throttle control system as a backup for use in the event of an emergency or a malfunction of an airplane's primary flight control system.

Introduction

The failure of primary flight control systems has resulted in numerous accidents. Most notably, United Airlines Flight 232, a DC-10, crash landed at Sioux City, Iowa on July 19, 1989. The flight crew saved many lives by skillfully steering using only the throttles. Following the accident, the National Transportation Safety Board informed NASA of the need to "encourage research and development of backup flight control systems for newly certified wide-body airplanes that utilize an alternate source of motive power separate from that source used for the conventional control system."

Propulsion Controlled Aircraft 3 (PCA 3) examined a low-cost, fly-by-throttle control system as a backup system for four-engine aircraft. The original control laws for PCA were developed by NASA Dryden Flight Research Center. Simulations with the Advanced Concepts Flight Simulator at CVSRF have investigated PCA in a two-engine aircraft, and Dryden has tested PCA with three engines using the MD-11. An earlier study in the 747-400 simulator applied PCA to a four-engine aircraft for the first time. In conjunction with Dryden, the Computational Sciences Division at NASA ARC conducted this simulation to determine if a simpler, less costly system for four-engine aircraft could be safely used.

Simulation

The PCA control laws essentially allowed subject pilots to fly the 747-400 Simulator using only the throttles for pitch and roll commands, without the use of the airplane's primary flight control systems. Pitch and roll commands were input via the vertical speed command and heading select knob on the airplane's Mode Control Panel whenever PCA mode was selected. Using the throttle commands, thrust inputs were translated through software into equivalent pitch and roll inputs, allowing pilots to maintain control of

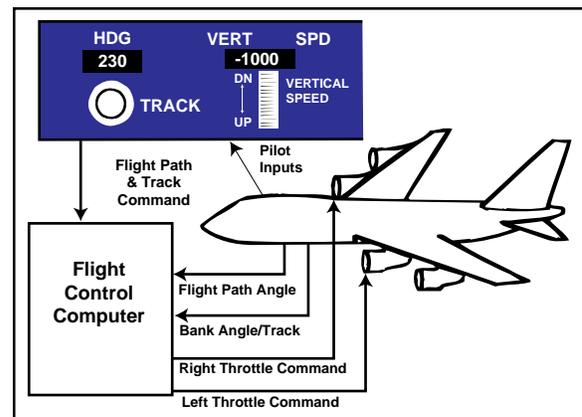
the malfunctioning aircraft. In the earlier PCA studies, symmetric and asymmetric engine pressure ratio commands from the flight computer were used to direct the 747's electronic engine controls, which bypassed the throttle servos. This study, however, utilized symmetrical pitch commands instead, which drove the aircraft throttle servos, while the pilots moved the throttles asymmetrically to control the aircraft roll angle.

Results

Test subjects came from NASA Dryden, NASA Langley Research Center, the U.S. Navy, and commercial airlines. They included Captain Al Haynes, pilot of the DC-10 that crash landed in Sioux City. Results indicated that, although PCA Ultralite is an improvement over manual throttle control alone, it does not provide landings as consistent or as safe as the PCA baseline tested previously.

Investigative Team

NASA Ames Research Center
CAELUM Research Corporation



Propulsion Controlled Aircraft 3 examined a low-cost, fly-by-throttle control system as a backup system for four-engine aircraft.

Obstacle Free Zone 1, 2

Frank Hasman, Allan Jones, Dave Lankford, FAA, Oklahoma City; Barry Scott, NASA ARC; Jerry Robinson, Boeing Commercial Airplane Group; Jerry Jones, Rod Kethcum, Diane Carpenter, NSI Technology Services Corp.

Summary

Two studies explored large aircarrier aircraft flight tracks and height loss arrest points as a result of crew-induced aborted landings after reaching decision height altitude in Category I and II weather conditions. The flight tracks and height loss arrest points were analyzed relative to Obstacle Free Zone space and dimension requirements.

Introduction

The Federal Aviation Administration's (FAA) *Advisory Circular 150/5300-13, Airport Design*, accounts for many elements including runways, shoulders, blast pads, clearways, runway safety areas, and adjacent taxiways. This advisory circular mandates Obstacle Free Zone (OFZ) dimensions for airplanes with wingspans up to 262 feet. For larger aircraft, information is needed for calculating the OFZ to provide safe conditions below the decision height.

The FAA's Flight Procedure Standards Branch conducted these simulations to assess various go-around call heights for the development of standards and operation criteria. The study was conducted in cooperation with the Boeing Company to additionally provide information for the design of new large aircraft.

Simulation

Two separate studies were conducted on the 747-400 Simulator during the fiscal year. The first test ran a series of approaches at New York's John F. Kennedy International Airport (JFK) and Mexico City. Flight track and height loss data occurring subsequent to arrival at Category I and Category II decision heights were collected for missed approach and aborted (balked) landings. Particular attention was

paid to all possible extreme wind conditions allowable for the type of approach being tested and to any possible impact on OFZ required space and on crew response and techniques. No variations in weight were conducted for these runs. Six days of data runs were completed for this study totaling 141 runs, utilizing line-qualified 747-400 flight crews. Data collection included digital readouts of aircraft state and performance data, videotapes and pilot questionnaires.

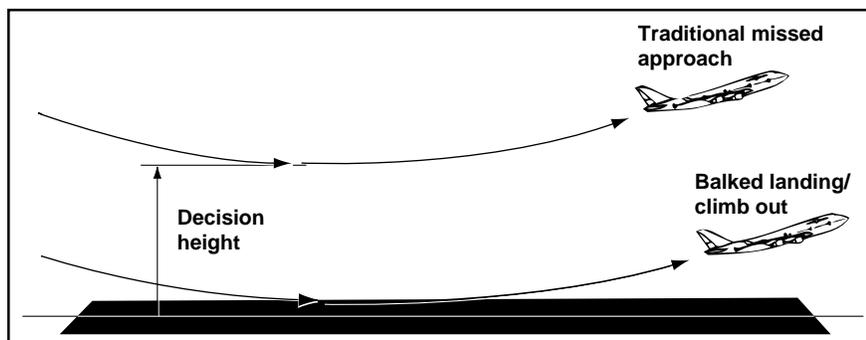
The second study focused additional attention on aborted takeoffs, engine-out takeoffs, and other variables such as airport traffic. Variations in gross weight were also examined. Test runs were simulated at JFK, Mexico City and Sao Paulo, Brazil. Eleven days of data runs were completed, totaling 198 runs. Overall, 17 days of data runs were completed for this program, totaling 339 runs.

Results

Test results will support Monte Carlo simulation studies using the FAA's Airspace Simulation and Analysis for TERPS (Terminal Procedures), which calculates the probabilities of collisions during aborted landings of new larger aircraft. This work will in turn assist the New Larger Airplane Working Group of the International Civil Aviation Organization in providing guidance in the introduction of new larger airplane operations to existing airports.

Investigative Team

Federal Aviation Administration, Oklahoma City
NASA Ames Research Center
Boeing Commercial Airplane Group



The Obstacle Free Zone will provide operationally safe conditions below the decision-height altitude.

Taxiway Navigation and Situation Awareness

Dave Foyle, NASA ARC; Dr. Robert McCann, SJSU; Don Bryant, Elliott Smith, Ian MacLure, NSI Technology Services Corp.

Summary

This study evaluated the use of a head-up display and an electronic moving map to provide navigation and guidance information to airplane flight crews for airport surface operations. The goal is to improve airport surface operations in bad weather and at night. Improving airport surface operations in bad weather and at night will increase airport capacity and improve aviation safety. This experiment supported the Low-Visibility Landing and Surface Operations (LVLASO) element of the Terminal Area Productivity (TAP) Program.

Introduction

Current airport surface operations are handled with verbal instructions over the radio, and the aircraft flight crew uses paper maps to navigate around the airport. In bad weather (low visibility) and at night, this can lead to very slow taxi operations and potentially dangerous situations. Under these conditions, many major U.S. airports have taxi capacity limitations, and several taxi accidents occur each year. Additionally, many commercial airliners now have electronic navigation displays and a head-up display installed, but they are not utilized in any significant way for taxi operations.

Simulation

The Taxiway Navigation and Situation Awareness (T-NASA) experiment introduced the concept of electronically loading the taxi route into an onboard system and displaying the route on both the head-up display (HUD) and the electronic moving map (EMM). Experiment runs started with crews flying on short final to one of several runways at Chicago's O'Hare airport. Following landing, the crews taxied to the terminal. The runs included baseline cases with only conventional verbal route and paper map, cases with the data-linked route and EMM, and cases with the data-linked route, EMM, and HUD.

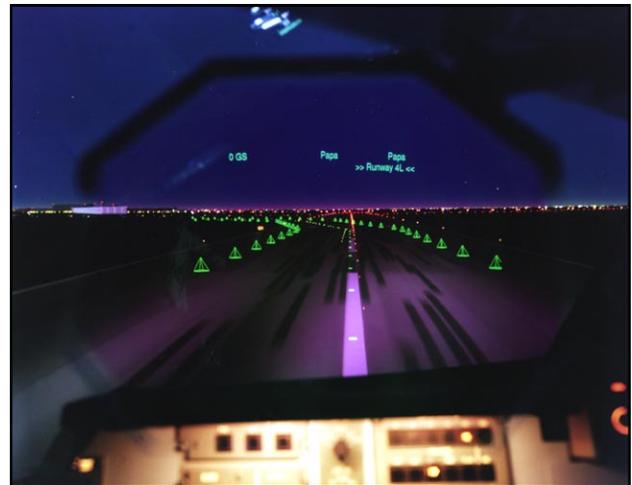
Results

Each crew performed 21 landing and taxi runs, with 38 airline pilots participating as crew members. Digital data of taxi performance was collected along

with video and audio recordings of the crews' activities. An extensive debrief was performed to get crew comments and opinions on the system. With the conventional configuration of only a paper map, numerous crews made navigational errors and had to slow down or stop to determine where they were at the airport. With the T-NASA HUD and EMM, the taxi runs were rapid and error free. The results indicate a significant overall decrease in taxi time with the T-NASA system and the elimination of potentially dangerous navigational errors. This can improve airline efficiency and provide the customer with better service at less cost, as well as improving aviation safety by decreasing accidents.

Investigative Team

NASA Ames Research Center
San Jose State University



This study evaluated the use of a head-up display and an electronic moving map to provide navigation and guidance information to the aircraft crew for airport surface operations in bad weather and at night.

Air-Ground Integration (Free Flight 3)

Sandy Lozito, NASA ARC; Alison McGann, Maggie Mackintosh, Paddy Cashion, Melisa Dunbar, Mike Montalvo, SJSU; Jerry Jones, Diane Carpenter, Ghislain Saillant, Rod Ketchum, Elliott Smith, NSI Technology Services Corp.

Summary

This study evaluated proposed airspace boundaries and investigated pilots' interpretations of Visual Flight Rules right-of-way procedures in the free-flight environment.

Introduction

Free flight is a traffic management concept that will allow pilots to fly routes of their own choosing, rather than routes dictated by air traffic control or by airline companies, thereby saving time and fuel. In support of NASA's Advanced Air Transportation Technologies Program, this series of simulations is evaluating human factors and performance issues, air-to-air communications, and varying traffic density levels as they relate to preventing conflicts in an envisioned free-flight environment.

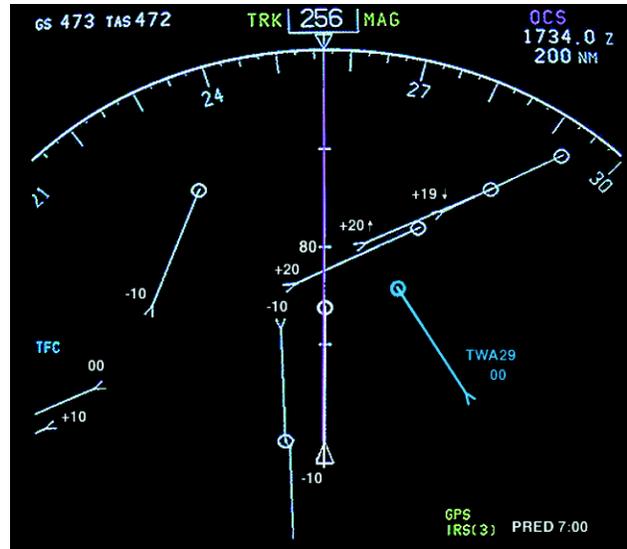
In support of free flight, an advanced alerting scheme logic has been implemented to provide safe airborne separation. The logic, developed by MIT, designates two zones around an aircraft similar to the current zones of the Traffic Alerting and Collision Avoidance System (TCAS). The first and smaller zone, named the protected zone, keeps a separation of five miles between aircraft and must not be violated. The second and larger zone, called the alert zone, is defined by a complex algorithm based on the relative positions of two aircraft, the probability of conflict, and the ability to maneuver out of conflict.

The Human-Automation Integration Research Branch of the Human Factors Division at NASA ARC conducted this study to evaluate these definitions and to assist in defining the roles and responsibilities of flight crews during the transgression of these zones.

Simulation

For this simulation series, new symbology was developed and integrated into the existing navigation displays. It displays aircraft up to 120 miles away, which is approximately 100 miles beyond the current TCAS zones. It also displays each aircraft's protected zone, absolute or relative altitude, and call sign. When the alert zones of two aircraft overlap, an aural warning is sounded, and temporal predictor lines can be displayed, indicating the predicted flight paths of nearby aircraft and the closest points of approach along those paths. A custom-built control panel allows the length of the temporal predictor lines to be adjusted to show flight paths for any amount of time up to ten minutes.

Also for this study, new communications software was developed and implemented to link the 747-400



In this display, the positions of intruder airplanes are depicted by chevrons as well as their predicted positions in seven minutes which are shown by the circles, and their corresponding predictor lines extrapolated from their current positions.

simulator to the Airspace Operations Laboratory at Ames, which simulated air traffic control and generated pseudo-aircraft for the experiment. Scenarios in Denver airspace were simulated. Line-qualified 747-400 flight crews and controllers from the Denver area participated in this study. Subject pilots monitored air traffic, negotiated with the crews of intruder aircraft, and executed avoidance maneuvers.

Results

This study completed 80 runs and measured variables including conflict detection time, communications timing, amount of communications with other aircraft, time to initiate maneuvers, procedures used to avoid conflicts, and closest point of approach between aircraft. The results will assist in developing airspace boundaries and procedural recommendations for future air-to-air negotiations in a free-flight environment.

Investigative Team

NASA Ames Research Center
San Jose State University

Turbulence for Precipitous Terrain

Alan Jones, Dave Lankford, FAA, Oklahoma City; Barry Scott, NASA ARC;
Jerry Jones, Diane Carpenter, Rod Ketchum, NSI Technology Services Corp.

Summary

This study evaluated the ability of pilots to fly through various levels of turbulence in an effort to quantify the effects of winds and turbulence induced by precipitous terrain.

Introduction

The FAA's Flight Procedures Standards Branch at the Aeronautical Center in Oklahoma City conducted a study on the 747-400 Simulator to examine issues related to precipitous terrain. Under the direction of the National Transportation Safety Board (NTSB) and industry, the FAA has been asked to examine the precipitous terrain issue with intent upon clearly defining precipitous terrain and specifying quantitative adjustments based upon that terrain. The FAA has a contract with the National Center for Atmospheric Research (NCAR) to evaluate the terrain aspects of this issue, including examining levels of turbulence and altimetry errors induced by precipitous terrain. A draft report released by the FAA and

NCAR on their efforts prior to this study cited two potential hazards for aircraft operations in the vicinity of precipitous terrain: terrain-induced altimeter errors and pilot control problems due to terrain-induced wind shear and turbulence. Currently, there is very little, if any, quantifiable information on the effects of turbulence and flight technical error (FTE) induced as a result of precipitous terrain. There are numerous anecdotal stories of control problems associated with turbulence, and there are some NTSB accident reports that list loss of control due to turbulence as one of the causal factors. As a first cut at this effort, this study attempted to quantify the effects of turbulence.

Results

In support of this effort, the FAA conducted a series of runs to observe pilot FTE under various levels of turbulence. Levels of turbulence for this test ranged between zero, moderate, and heavy. Runs

consisted of a series of approaches starting approximately 15 miles out, with crews being instructed to land under the varying levels of turbulence. Test runs were flown both manually and with the autoflight system. To account for variations in altitude, approaches were conducted at New York's John F. Kennedy International Airport and at Denver International. This test used in-house NASA pilots. Overall, eight pilots participated in this study, totaling 72 runs. The results of this study will help to establish a baseline for quantifying the effects of turbulence induced by precipitous terrain on pilot FTE.

Investigative Team

Federal Aviation Administration, Oklahoma City
NASA Ames Research Center



This study evaluated the ability of pilots to fly through various levels of turbulence in an effort to quantify the effects of winds and turbulence induced by precipitous terrain.

Fatigue Countermeasures

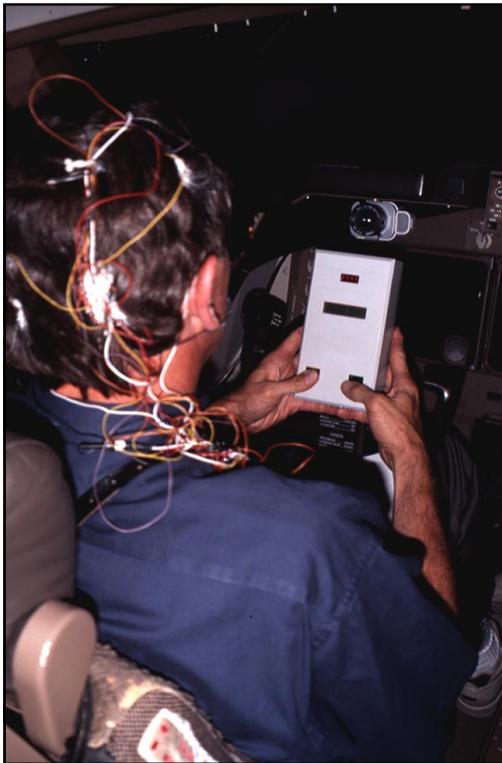
Dr. David Neri, NASA ARC; Ray Oyung, SJSU;
Jerry Jones, Rod Ketchum, Diane Carpenter, NSI Technology Services Corp.

Summary

This study investigated the effectiveness of an in-flight countermeasure to the fatiguing effects of a long, overnight flight such as those encountered during transoceanic trips today.

Introduction

A study conducted on the 747-400 Simulator by the System Safety Research Branch in NASA's Human Factors Division investigated the effectiveness of an in-flight countermeasure to the fatiguing effects of a long, overnight flight and evaluated the utility of a new technique for the measurement of drowsiness and fatigue. Long, uneventful flights characterized by physical inactivity, the requirement to remain vigilant for low-frequency occurrences, low light levels, limited social and cognitive interaction, and minimal environmental manipulations present a situation in which any underlying sleepiness is likely to emerge. This sleepiness can then result in compromised vigilance, reduced alertness, and impaired performance. If the flight occurs during nighttime



During this investigation of fatigue countermeasures, pilots performed a ten-minute psychomotor vigilance test at regularly scheduled intervals.

hours, the levels of fatigue and sleepiness are increased and can significantly effect safety.

Countermeasures to fatigue are needed, but the possibilities are limited by aviation regulations, various safety concerns, and the cockpit environment itself. Laboratory studies have demonstrated the effectiveness of breaks, physical activity, and social interaction in ameliorating the decline in alertness and performance. This experiment examined the effectiveness of regularly scheduled breaks and physical activity on the ability to maintain vigilance and to mitigate the fatigue-inducing effects of nighttime flying. This investigation also examined the utility of using a new technique for detecting the presence of fatigue. This methodology, Percent Closed (PERCLOS), requires a careful video recording of the face and eyes. Recent laboratory investigations have shown PERCLOS to provide an extremely promising metric of drowsiness. Online measurement in the future has the potential to play a key role in an alertness management system, providing feedback to the pilot on his or her physiological state.

Results

Experiment runs began at approximately 2:00 a.m. to take advantage of the time when flight crews would feel the effects of fatigue the most. For this study, subject pilots were instrumented with surface scalp and face electrodes for the collection of electroencephalography (EEG) and electromyography (EMG) data in order to ascertain their alertness levels and detect any micro sleeps. Test subjects were broken up into two different control groups. One group was given minimal rest breaks while the other had more frequent breaks. At regularly scheduled intervals during the simulation, subject pilots were asked to perform a 10 minute psychomotor vigilance task on a portable, battery-operated, hand-held device. Pilots also continuously wore wrist actigraphs as an additional objective measure of sleep/wake state and overall activity. The actigraph was an activity monitor the size of a watch and was worn by the pilots throughout the three-day pre-study period, as well as during the simulation run. Overall, 14 crews took part in the study. Data recorded included videotapes, digital recordings of aircraft performance and state information, pilot questionnaires, and physiological data.

Investigative Team

NASA Ames Research Center
San Jose State University

Propulsion Controlled Aircraft 4 (Ultralite)

John Kaneshige, NASA ARC;

Don Bryant, Diane Carpenter, NSI Technology Services Corp.

Summary

Several airline and military aircraft have crashed after having systems fail that cause partial or complete loss of control of the conventional control surfaces (rudder, aileron, elevator, flaps, slats). The Propulsion Controlled Aircraft system utilizes engine thrust only to control the aircraft and safely land. This experiment studied a simplified Propulsion Controlled Aircraft design (Ultralite) that may be affordable for retrofit into existing airline fleets.

Introduction

The NASA Propulsion Controlled Aircraft (PCA) research program has developed engine control systems that provide excellent control capabilities to vehicles that have lost conventional controls. This research has included past experiments on the ACFS and 747 simulators as well as flight tests on a McDonnell Douglas MD-11 aircraft. The cost to retrofit these complete systems into existing airline fleets would be very high. This PCA experiment investigated different levels of automation to evaluate the usefulness of systems that could potentially be retrofitted to existing aircraft at significantly lower cost.

The specific automation configurations investigated included automatic symmetric and manual asymmetric engine thrust control (called PCA Ultralite), manual symmetric and asymmetric engine

thrust control, with the use of either conventional PCA or PCA flight director mode.

Results

Test pilots from three NASA Centers, the FAA, the Airline Pilots Association, and several airlines all evaluated the system. Early results indicate that both flight director modes significantly improved the crew's ability to land safely, and the PCA Ultralite throttle system also helped significantly. Additional experiments are planned for the 747-400 simulator at NASA Ames and for flight tests on board the NASA 757 aircraft as part of the Aviation Safety Program.

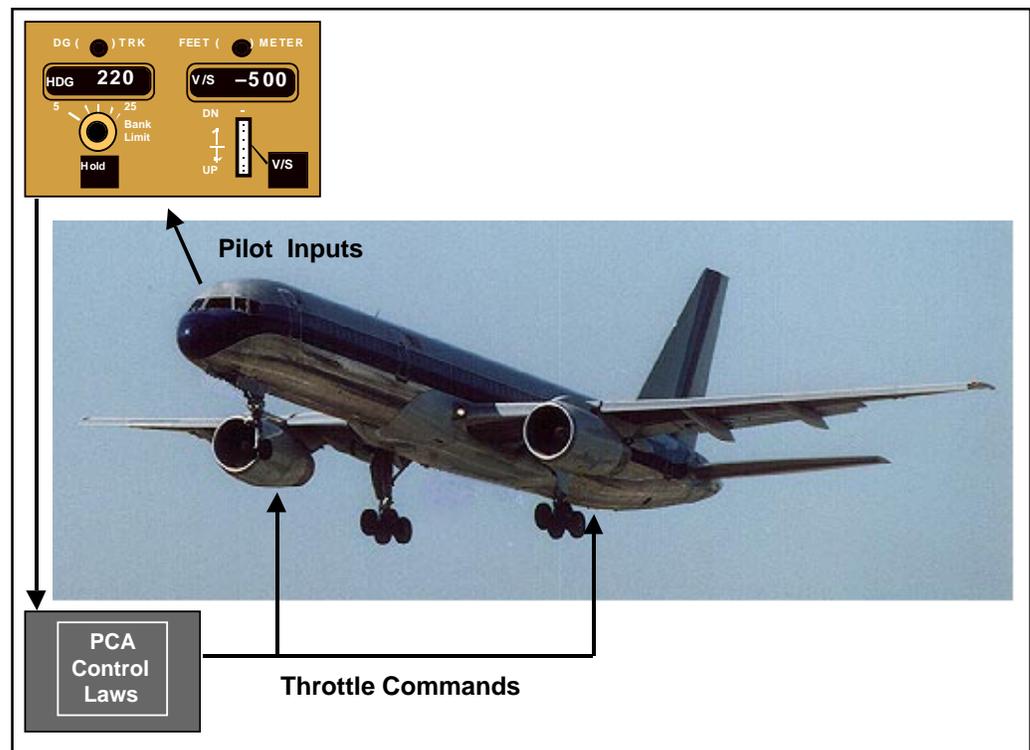
Investigative Team

NASA Ames Research Center

NASA Dryden Flight Research Center

John S. Bull, Independent Contractor

Foothill DeAnza Community College



The PCA concept is to control a damaged aircraft through the use of throttles only.

Advanced Automation Qualification

Dr. Stephen Casner, NASA ARC;
Jerry Jones, Rod Ketchum, NSI Technology Services Corp.

Summary

This study evaluated the effectiveness of a training curriculum designed to teach flight deck automation concepts and skills to a level of understanding beyond that which is taught in current airline training practice.

Introduction

The Human Automation Integration Research Branch in NASA's Human Factors Division conducted a study on the 747-400 Simulator to evaluate the effectiveness of a training curriculum designed to teach flight deck automation concepts and skills to a level of understanding beyond that taught by the airlines today.

This study consisted of two parts. In the first part, multiengine commercial instrument pilots who are currently seeking airline jobs participated in a classroom training program designed to teach advanced flight deck automation skills and concepts. This portion of the study took place outside of the CVSRF and required no participation or support from the CVSRF.

The second part of the study evaluated the effectiveness of the classroom training. This part of the study was conducted in the 747-400 simulator. This part of the study simulated a check ride given by an FAA Designated Examiner, who was provided by the researcher. The aim of the check ride was to evaluate to what extent the participants of the study had mastered the concepts and skills presented in the classroom training.

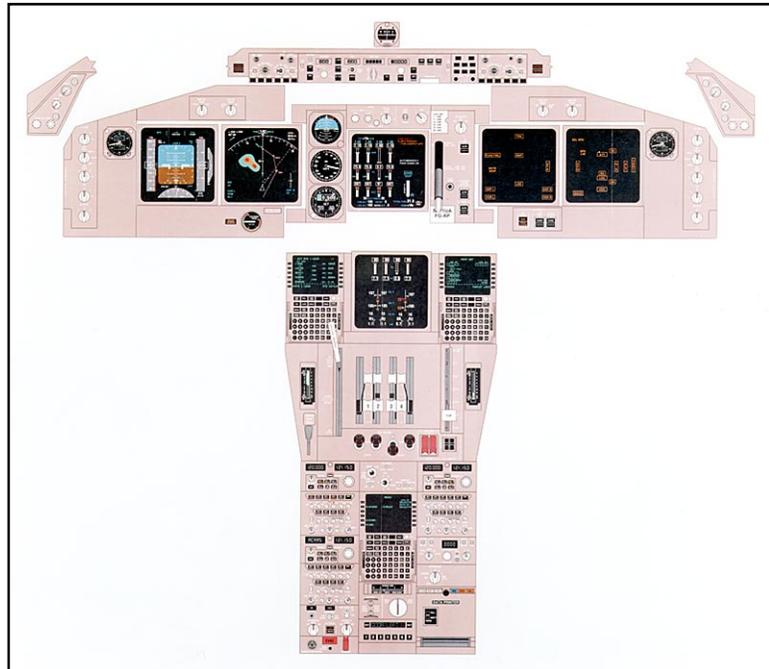
Results

In support of this study, each participating subject flew two legs in the simulator. The first leg was a familiarization flight

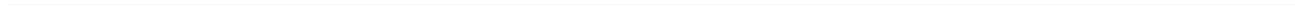
originating in Los Angeles and landing in San Francisco. The second flight began in San Francisco and concluded with a landing at Los Angeles. During this flight, the Designated Examiner conducted the simulated check ride. Overall, eight pilots participated in this study. Each leg of the experiment was videotaped and is currently being analyzed. However, preliminary results indicate that the participating subjects performed fairly well, indicating the effectiveness of the earlier training curriculum.

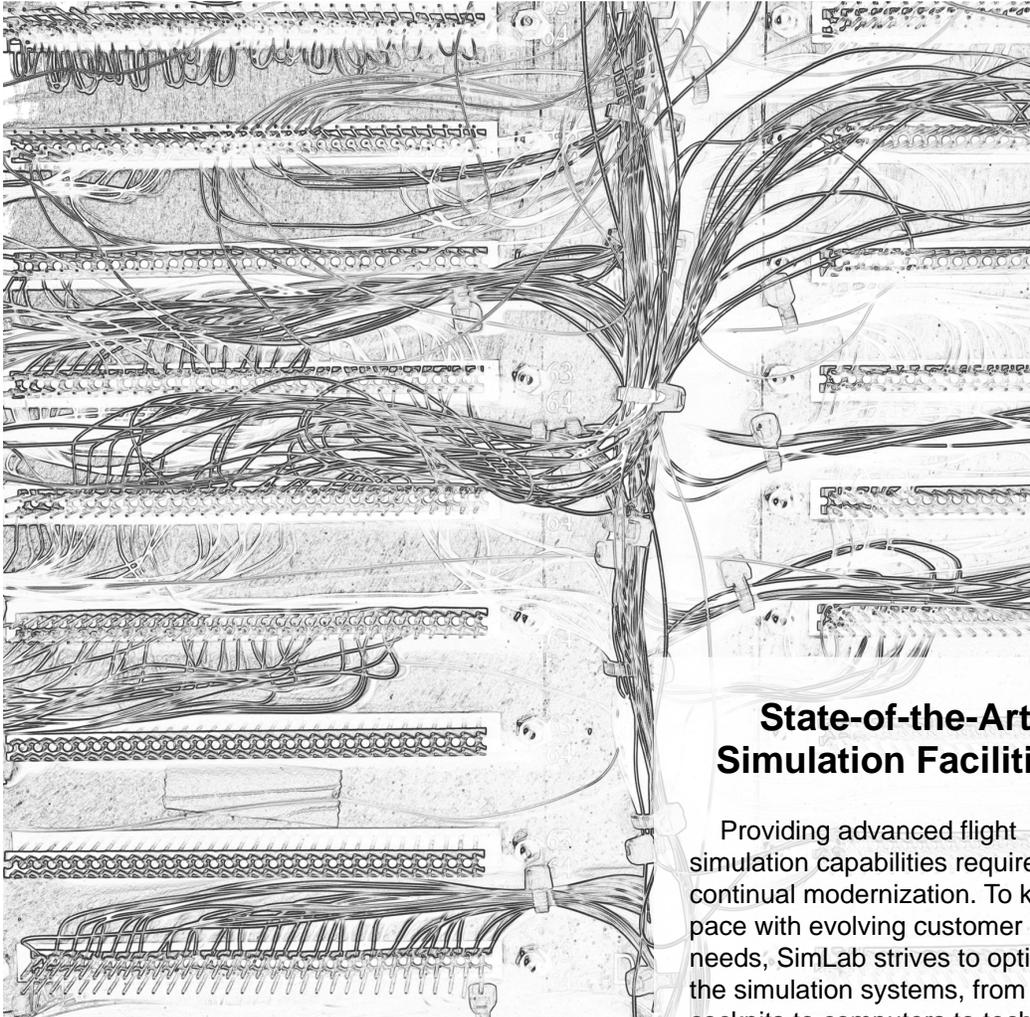
Investigative Team

NASA Ames Research Center



The flight deck of the 747-400 Simulator used to test flight deck automation concepts and skills.





State-of-the-Art Simulation Facilities

Providing advanced flight simulation capabilities requires continual modernization. To keep pace with evolving customer needs, SimLab strives to optimize the simulation systems, from cockpits to computers to technology for real-time networking with flight simulators and laboratories in remote locations.

Virtual Laboratory

Introduction

The Virtual Laboratory (VLAB) represents a fresh approach to conducting simulation experiments. It allows researchers at remote sites to interactively participate in live simulation experiments conducted in research laboratories at the Ames Research Center.

Using a virtual reality environment, remote users can monitor various simulation data as if they were physically present in the VMS complex. In addition, they can view the pilot's front-window scene, head-up and head-down displays, a graphical depiction of the motion platform, strip charts, and end-of-run data displays. Also integrated into the package are two-way communication, video conferencing, and ambient sound capabilities that enable the remote user to direct the experiment. Future versions of VLAB will feature simulation model control, aircraft controls,

Space Shuttle orbiter at Ames. During the semi-annual Shuttle simulations, VLAB is deployed to NASA Johnson Space Center (JSC) to enable researchers to remotely monitor and interact with simulations and to capture data for analysis. This marked the first time the full VLAB client used a public network, the NASA Science Internet Network. Data transmission, including video of the out-the-window display, achieved rates from Ames to JSC and back between 50 and 150 milliseconds. For the first time, JSC researchers did not come to Ames, but relied solely on VLAB to conduct the necessary research. Their reliance on VLAB's many remote capabilities validated VLAB in theory and in practice.

Supercomputing '97

VLAB was invited to participate in the 1997 Supercomputing High Performance Networking and

Computing Conference (SC'97) held November 17-21 in San Jose, California. Using joystick interfaces, exhibit visitors were able to navigate in real time through the three-dimensional virtual laboratory during an actual flight simulation experiment. Users could view data, the pilot's front-window scene, cockpit displays, and a graphical depiction of the VMS beam in motion, in addition to communicating with researchers via two-way video conferencing.

Future Plans

Future work will include enhancing the fidelity of the immersive nature of VLAB; providing additional user input/output features; increasing VLAB's applicability to several simulation experiments; collaborating with technology experts, both within and outside of Ames; and increasing its diversity by applying the VLAB technology in areas beyond flight

simulation at the VMS. Other plans include exploring possible partnerships with educational institutions and with local aeronautics museums.

Development Team

Russell Sansom, Chuck Gregory, Rachel Wang-Yeh, Daniel Wilkins, Logicon Syscon/Syre

For more information, visit VLAB's web site:
<http://www.simlabs.arc.nasa.gov/vlab>.



Using VLAB, researchers in remote locations monitor and interact with VMS simulations as they occur.

display development, virtual prototyping, and data browsing.

VLAB embodies Ames Research Center's mission to lead the world in Information Technology. It allows government and industry greater access to NASA expertise in a hands-on fashion. VLAB is an extension of a national research facility that enables industry to improve and accelerate its design process, yielding cutting-edge aeronautical products.

Deployment to Johnson Space Center

VLAB's most important deployment to date occurred this September during the simulation of the

Out-the-Window 2000 Plus

Summary

To greatly enhance the real-time out-the-window image capabilities of the VMS, an engineering project, designated Out-the-Window 2000 Plus, combined two image generators into a single, powerful unit at a significant savings over purchasing an equivalent system.

Introduction

Through 1997, the VMS real-time out-the-window scenery was generated by an Evans and Sutherland CT5A and by an Evans and Sutherland Image Generator (ESIG) 3000. The CT5A was limited to three video channels, low object counts, and textureless polygons, which no longer met researcher demands for realism or scene detail in visual cueing. Due to the low performance of the CT5A, demands on the ESIG 3000 escalated. Out-the-Window 2000 Plus (OTW2K+) was formed to replace the CT5A with a system that would provide state-of-the-art imagery beyond the year 2000.

Requirements for the new system included compatibility with existing legacy software and with an extensive library of visual databases. Implementation needed to occur without significant change to the interface with the rest of the simulation system. Only commercial off-the-shelf systems would be considered to avoid the high cost, complexity, and maintenance of a custom-built system. Additionally, OTW2K+ was the first VMS project to follow ISO 9000 procedures.

Project Description

After the establishment of formal project requirements, a surplus three-channel ESIG 4530 became available from NASA Johnson Space Center (JSC). Project personnel determined that the surplus unit and an additional new unit could be acquired and merged into a single system, fulfilling the project requirements at a significant savings over the alternatives. The VMS purchased the 4530 from JSC and contracted with Evans and Sutherland to supply a new two-channel ESIG 4530. OTW2K+ then integrated the two machines.

The 4500 series software required several modifications. The network interface software was changed to allow connection to the multi-node network by ignoring broadcast packets. The video generation software was modified to enable operation in external sync mode and with the XKD 8000 out-the-window monitors. Evans and Sutherland modified some software, and software was also incorporated from the ESIG 3000 on site.

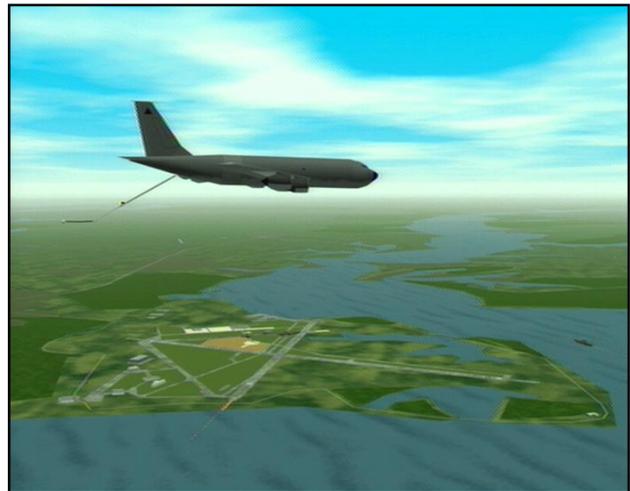
Results

The new system underwent an extensive series of tests and became operational without disruption to the simulation schedule on April 14, 1998. ISO 9000 standards were met and included the procurement of spares and maintenance, as well as training for personnel involved in visual database development, system hardware maintenance, and simulation engineering.

By acquiring and physically merging two low-cost image generators and customizing the system software, the VMS efficiently produced a powerful machine with five video channels. The new system features high resolution, MIPS texture, and high object counts. With dual CPUs and dual VME buses, the new system can be configured for two independent eye points.

Development Team

Doug Greaves, NASA ARC; Timothy Trammell, Ernest Inn, Cary Wales, Jeffery Dewey, Logicon Syscon/Syre



Out-the-Window 2000 Plus (OTW2K+) was formed to replace the CT5A with a system that would provide state-of-the-art imagery beyond the year 2000. The new system features high resolution, MIPS texture, and high object counts.

Host Computer Upgrade

Summary

To meet the computing requirements of today's most demanding simulations, Host Computer Upgrade '98 replaced existing host computers with new systems that exhibit the potential to meet the simulation needs of the VMS well into the new century.

Introduction

Host Computer Upgrade '98 integrated new, higher-performance host computers into the VMS complex. The new systems replaced host computers that could not meet the anticipated computing requirements of three specific simulations scheduled for FY98 and FY99. The requirements of the simulations called for drastic increases of between 1.5 to 2.5 times the performance of the existing systems. The project had three principal requirements: computing power capable of meeting future simulation needs, functionality similar to that provided by the systems being replaced, and the ability to obtain repairs in the same time frame.

Performance

Considering that the current computers had been in place less than three years and that they represented a twofold increase in speed over the previous machines, meeting the specifications was problematic. However, due to the computer industry's improvements in chip computing frequencies and feature capabilities, it was possible to purchase computer systems with the necessary performance from the manufacturer of the existing machines, thereby meeting all three requirements.

The new hosts are Digital Equipment Corp. AlphaServer 1000A 5/500 machines, replacing AlphaServer 1000 4/233s. Benchmark figures from the Standard Performance Evaluation Corporation

(SPEC, a standardization body) indicated a 3.3 times improvement in speed. Using the same manufacturer's operating system allowed the same user functionality features. The repair time requirement was maintained easily across machines with identical warranties. This solution provided a relatively easy means of satisfying the requirements, although there were some changes in the laboratory interfaces that required upgrade to and modification of certain input/output (I/O) circuit board sets.

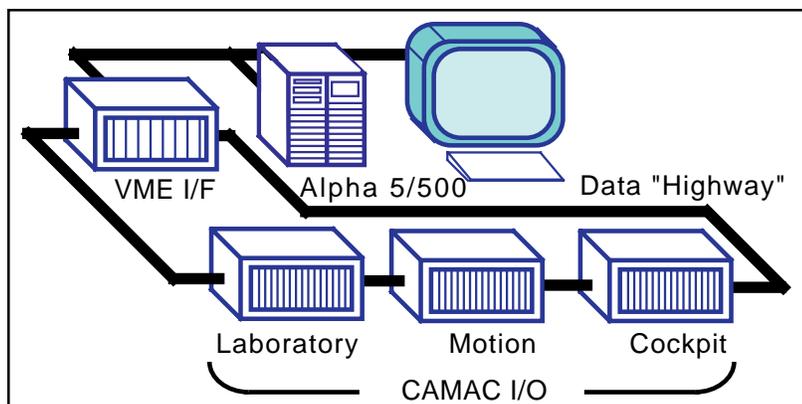
The performance increase of the operational systems easily exceeded the requirements of the FY98 simulations. Taken together with the CAMAC interface to the cockpit and labs, the VMS system is capable of frame times of less than one millisecond when only I/O is performed with the motion, laboratory, and cockpit subsystems. Adding the typical aircraft model allows frame times as short as 2 milliseconds. As a practical matter, most simulations are run at longer frame times, such as 12.5 milliseconds (80 cycles per second), which is more compatible with the 16 2/3 millisecond field time of the associated graphics generators.

Results

The integration of the new systems was completed in the motion-base lab and in one of the supporting laboratories. An additional laboratory upgrade is anticipated for FY99. The new systems are capable of speeds 2.5 times faster than the systems they replaced. By the end of FY98, the new host computer system had been used successfully in both of the year's required simulations.

Development Team

William Cleveland, NASA ARC; Bosco Dias, Estela Hernandez, Hai Huynh, Martin Pethel, Logicon Syscon/Syre



The host simulation computers interface to the laboratory, cockpit, and motion systems. The new host provides frame times down to two milliseconds, depending on the complexity of the aircraft model.

Real-Time Network Upgrade

Summary

An upgrade of the real-time network at VMS significantly increased network performance, functionality, and configurability while allowing for future upgrades to developing network technologies.

Introduction

Until recently, switching for the real-time network at VMS was controlled by two 10Base5 half-duplex switches. Under this system, network connections to the three host computers approached saturation. To remedy the situation, and to make the network more functional and more configurable, the switches were replaced by a Xylan OmniSwitch 5.

Features and Performance

- Full-duplex 100 megabits per second (Mbps) Ethernet (Fast Ethernet) - boosts the speed of host computer connections by approximately 20 times and eliminates Ethernet collisions. Response time of the Evans and Sutherland Image Generators (ESIGs) is significantly more predictable. Attempts to load the network revealed no measurable changes to the response time of the ESIGs or to the input/output frame timing of the host computer's software.
- Thirty-six 10/100 auto sensing ports - increase the number of devices that can be networked. Ports communicate at 10 Mbps or 100 Mbps, according to each device's capability.
- Low, predictable latency - ensures that packets are passed quickly and consistently.
- Console interface - allows engineers to monitor the system status, change configuration settings, save configuration files, and upgrade the firmware.
- Out-of-band packet analysis - makes possible the analysis of network performance without disruption to real-time operation.
- Address manipulation - enables the assignment of permanent addresses and the configuration of address aging.

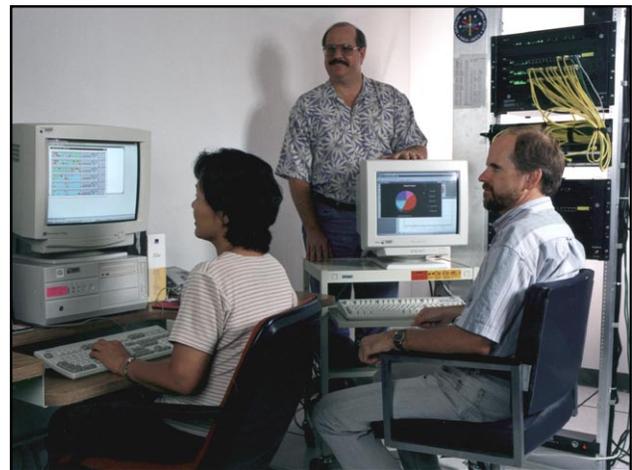
- Virtual Local Area Network (VLAN) capability - allows the 36 ports to be split into two isolated networks; 34 ports were assigned to the real-time network and 2 ports to the development network.
- Modular components - enable easy expansion and upgrades, including firmware.

Results

The real-time network upgrade replaced a dual 10 Mbps half-duplex network with a highly configurable 10/100 Mbps full-duplex network. Transition to the new network was achieved with no disruption to the VMS simulation schedule. The increased performance of the host connection allows more Ethernet input/output to be added to the host computer software if needed. The new system provides superior monitoring and control capabilities. Lastly, the modular components allow for expansion of the Ethernet ports and for upgrade to future network technologies.

Principal Contributor

Martin Pethtel, Logicon Syscon/Syre



The Real-Time Network switch (far right) and two network management stations.

Bosnia Visual Database

Summary

SimLab developed its largest visual database to date in a very limited amount of time for use in U.S. Army simulators. The highly detailed Bosnia database is used to conduct aviation training exercises and to practice military planning and decision making.

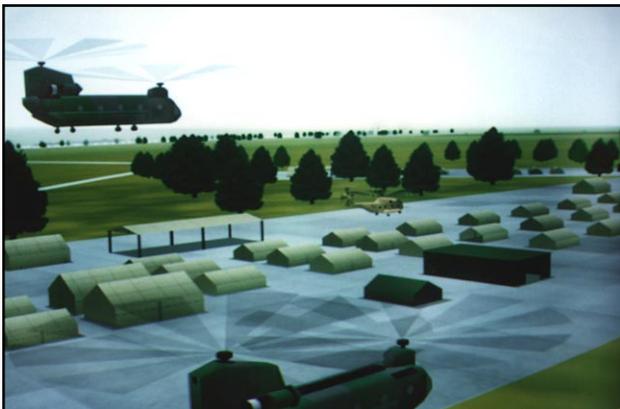
Introduction

The U.S. Army's presence in Bosnia requires full-mission rehearsal of aviation mission critical tasks prior to troop deployment. These simulations are vital for mission training and for exercises in military planning and decision making. The Army's Aviation Center had relied on a visual database that simulated terrain from Germany with features specific to Bosnia, but troops found the database to be significantly different from the actual environment. Pre-deployment training with an accurate database became more important in light of the ongoing U.S./U.N. peacekeeping mission. Thus, the Army's Directorate of Training Doctrine and Simulation (DOTDS) called on SimLab to develop its largest database ever in the extremely short period of four months.

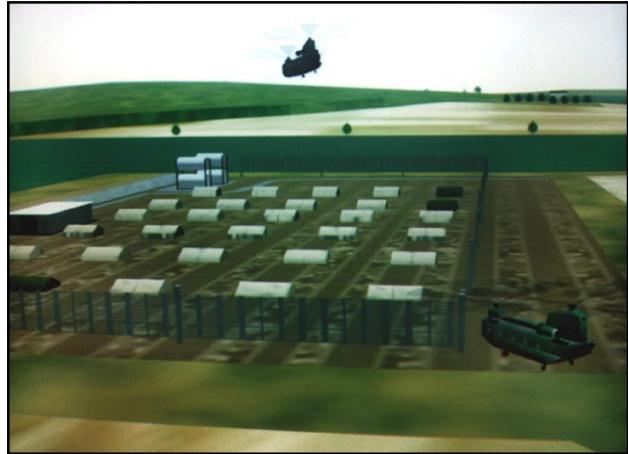
Database

The Bosnia database required a high level of detail to support nap-of-the-earth flight over an area 130 X 130 kilometers with visibility of eight kilometers. DOTDS provided digital terrain elevation data, vectorized digital feature analysis data, and maps and photographs of important features. DOTDS also provided positional data for the nine required base camps, airfields, and command posts.

The database was developed in nine sections,



SimLab developed its largest visual database to support the U.S./U.N. peacekeeping mission in Bosnia.



The Bosnia Visual Database is used to conduct aviation training exercises and to practice military planning and decision making.

each approximately the size of the average VMS database. To support the high level of detail required, gridpost spacing of 300 feet was established. The terrain was designed to have six levels of detail and a homogenous topological hierarchy, except in regions that were flattened to accommodate large-scale features such as airports and base camps. The database consisted of 2025 modules, each measuring 9600 feet on a side.

Two three-dimensional forest basis sets and three urban basis sets were developed, requiring new models for buildings and trees. Numerous urban sites also required custom models. A detailed model was created for the Tuzla airfield, and unique sites were produced for the Comanche, McGovern, and Alicia base camps. The McGovern base camp served as a generic model for camps at additional locations. Models were created for ammunition dumps, power plants, and industrial sites. All polygons were assigned infrared codes for use with night vision goggles during the simulation of nighttime conditions.

Results

VMS staff produced its largest database to date. The project required a high level of detail yet was completed in just four months. This project demonstrated the ability of VMS to create large and complex databases for off-site use by VMS customers.

Development Team

Dave Carothers, Gloria Lane, Cary Wales, Logicon Syscon/Syre

Joint FAA/Army/NASA Interoperability Demonstration

Summary

The Department of Defense is developing a new method for interconnecting simulations called High Level Architecture and has mandated that all Department of Defense simulators use this system. In order to evaluate the potential of this new system for assisting NASA in performing aviation research, a test federation was developed with two primary customers of the simulation facilities, the U.S. Army and the Federal Aviation Administration. The team successfully demonstrated the technology and identified many strengths and a few potential problems with this new system.

Introduction

In order to perform advanced airspace operations research, it is becoming increasingly necessary to interconnect more and more simulators during one experiment. This can be a difficult and time-consuming effort. Current methods utilized at NASA ARC and the Federal Aviation Administration (FAA) Technical Center in New Jersey are based on ad hoc methods and standards as needed for each experiment. The Department of Defense (DOD) has mandated that for their integrated experiments, all simulators will utilize a new system of software and conventions called High Level Architecture (HLA). Personnel from NASA Ames, the FAA, and the U.S. Army (located at Ames) determined that the best method to evaluate this technology was to develop a demonstration experi-

ment utilizing components from each facility.

Results

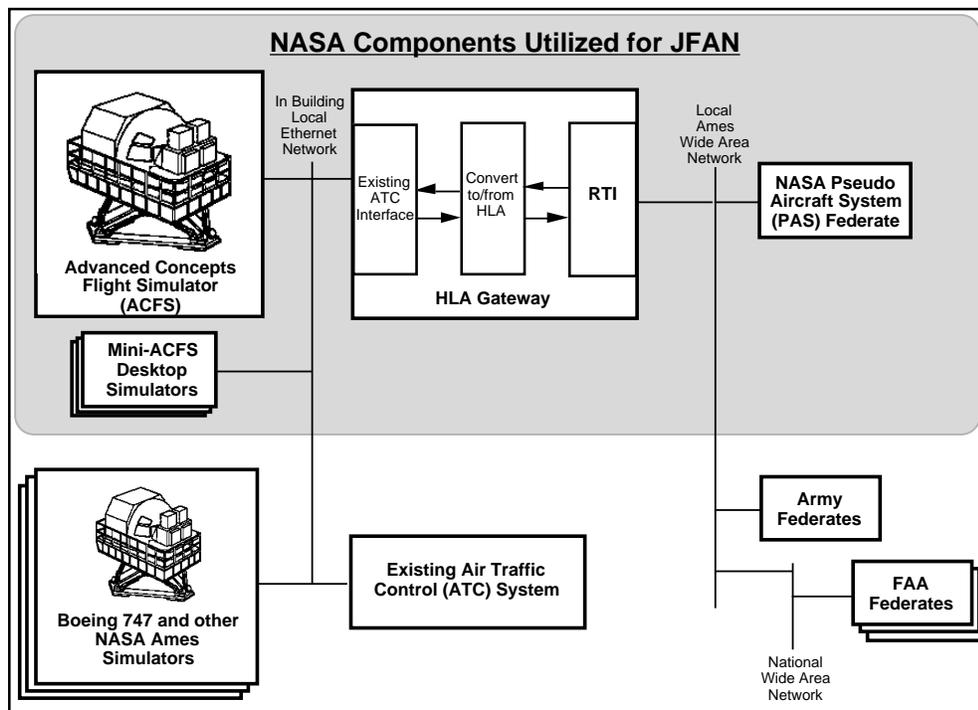
The Advanced Concepts Flight Simulator (ACFS) and several desk-top copies of the simulation (called the Mini-ACFS) at CVSRF were flown in real-time, networked to the Army's helicopter simulator and tactical environment simulation and to the FAA's Micro Target Generation Facility (MTGF), Air Traffic Control Test Federate (ATCTF), and Cockpit Simulation Facility (CSF). All aircraft flew conventional approaches to San Francisco International Airport. The aircraft generated by the Army and FAA simulations were visible on the navigation display as well as on the out-the-window visual system on the ACFS. Timing and performance data were collected and reported to the DOD sponsor for HLA activities, the Simulation Interoperability Standards Organization (SISO). The system provided a good framework for networking large numbers of different simulators.

Investigative Team

NASA Ames Research Center
 Federal Aviation Administration
 U.S. Army

Project Support Team

Matthew Blake, NASA ARC; Craig Pires, Hector Reyes, NSI Technology Services Corporation



CVSRF, in conjunction with the FAA and the U.S. Army, demonstrated a new system of software and conventions that interconnects simulators during a single experiment.

Flight Management System Upgrade

Summary

In order to perform advanced research in cockpit systems, the Advanced Concepts Flight Simulator (ACFS) utilizes a software-programmable Flight Management System (FMS) rather than aircraft hardware. A two-year project to significantly improve the FMS was completed this year. The system is believed to be unique in the world in terms of the datalink capabilities and the programmable flexibility required for advanced airspace operations and automation research.

Introduction

Modern commercial transport aircraft include an extremely complex onboard computational system called a Flight Management System (FMS). The FMS can be programmed to fly complete routes anywhere in the world. Due to the extreme complexity of these systems, most commercial transport aircraft simulators use actual FMS hardware from the aircraft that cannot be modified for research purposes. However, the complexity of a modern FMS and its often cumbersome interface can lead to many human-factors research issues pertaining to efficient and safe operations.

To address these problems, the ACFS was fitted with a software-programmable FMS that was originally developed by Boeing for their engineering flight simulator. This system proved inadequate, and a joint Integrated Product Team of personnel from the simulation facilities and from the primary research organization was formed to improve the system. The enhanced FMS was integrated into the ACFS this year and is being used for the CTAS-FMS Datalink experiment. This same system is available to the Ames research community for use in a desktop environment called the Mini-ACFS.

Results

The majority of the basic functions available in a state-of-the-art commercial FMS are also available in this research version. Most of the advanced features relate to airborne datalink and its interface with ground-based Air Traffic Management (ATM) systems, specifically the Center TRACON Automation System (CTAS). The system provides the capability to transmit a descent clearance from CTAS directly into the FMS, which then automatically modifies the flight plan with the clearance route. This capability to link directly into the FMS and modify the flight plan is unique in the world. An additional benefit of the software FMS is the ability to collect data on how the FMS performs internally and how the crew interacts

with it. Much of this information cannot be collected from experiments utilizing flight hardware for the FMS function. In the future, the FMS will continue to be enhanced as needed to support the specific research goals of the airspace capacity, safety, and base research efforts at Ames.

Project Support Team

Matthew Blake, Barry Sullivan, NASA ARC; Ramesh Panda, Don Bryant, NSI Technology Services Corporation; Mietek Steglinski, Steglinski Engineering; John Kaneshige, NASA ARC; Arun Jain, Raytheon



An enhanced, software-programmable Flight Management System was integrated into the ACFS. This type of system enables a ground-based Air Traffic Management System to link directly into the FMS and modify the flight plan.

Communications System Upgrade

Summary

Experiments at the CVSRF require simulation of a complete VHF radio communication system including dozens of stations, frequencies, and interconnection requirements. The existing system had limited capability and was no longer maintainable. A complete, new system supporting the 747-400 simulator, the ACFS, and the ATC simulator was developed and installed. This system provides an extremely flexible, state-of-the-art digital voice communication capability and can support connections to other facilities worldwide.

Introduction

The ATC COMM System upgrade uses Advanced Systems Technology Inc. (ASTi) Digital Audio Systems (DAS) and ASTi digitized voice interface protocol (VoiceNet) components. The ASTi DAS has the capacity for 24 different channels, a VoiceNet networking capability for connecting several ASTi DAS, and a software circuit design user interface called the Model Builder. The Model Builder provides flexibility for installing and modifying radio and sound applications.

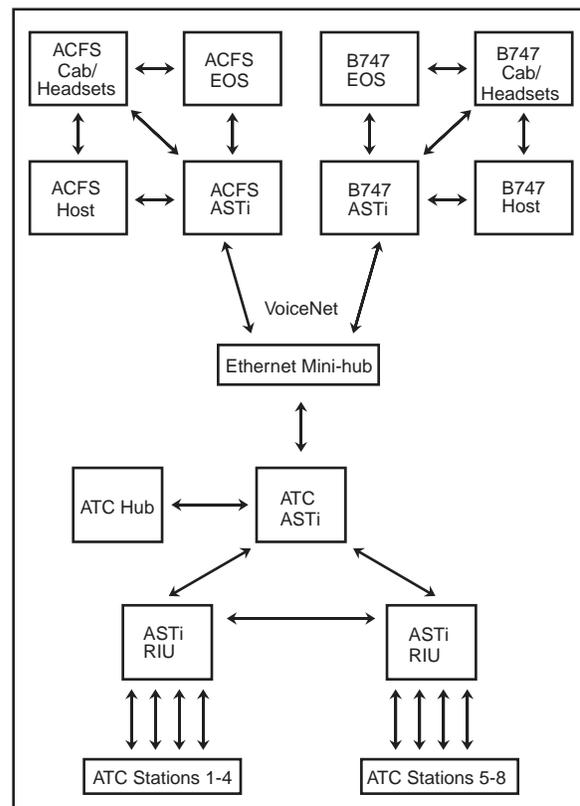
There are three ASTi DAS, one for each simulator, which are connected via VoiceNet. The ACFS Cockpit and ACFS Experimenter-Operator Station (EOS) share an ASTi DAS for intra-communication, control of the experiment, and communication with the other simulators. The 747 ASTi DAS has a radio model for communication with the ATC and ACFS; the EOS communication was already provided by the 747. The ATC ASTi DAS provides the radio model for eight ATC Stations in the ATC Lab, which also communicate with the ACFS and 747. ASTi models have been implemented, which provide intercommunication between all three simulators, between the ATC and ACFS, or between the ATC and B747. All sound levels are controlled locally by each user. Different station configuration setups can be loaded in the ATC ASTi DAS through an Ethernet connection to the ATC Hub computer.

Results

The new Communication System was used successfully for the T-NASA experiment. The flexible, programmable ASTi system provides an excellent Communication System for supporting research experiments that each have unique communication requirements. The new system has the flexibility to be used in experiments involving any combination of the three simulators and can easily be connected to simulators at remote locations.

Project Support Team

Matthew Blake, NASA ARC; Hector Reyes, Eric Jacobs, John Guenther, Glenn Ellis, Vic Loesche, Craig Pires, NSI Technology Services Corporation



Communication System Upgrade schematic. Each ASTi Remote Interface Unit services four ATC stations.

List of Acronyms

AAQ	Advanced Automation Qualification
AATT	Advanced Air Transportation Technologies
ACAH	attitude command/attitude hold
ACFS	Advanced Concepts Flight Simulator
ACT	active control technology
AFCS	automatic flight control system
AFDD	Aeroflightdynamics Directorate, U.S. Army
AMCOM	Aviation and Missile Command, U.S. Army
AOS	Airspace Operations Systems
ARC	Ames Research Center
ASTi	Advanced Systems Technology Inc.
ATC	Air Traffic Control
CDA	Concept Demonstrator Aircraft
CH-47D	Chinook heavy cargo helicopter
CPU	central processing unit
CTAS	Center TRACON Automation System
CTR	Civil Tiltrotor
CVSRF	Crew-Vehicle Systems Research Facility
DAS	Digital Audio Systems
DASE	Dynamic Aero Servo Elastic
DEC	Decision Making
DERA	Defense Evaluation and Research Agency, United Kingdom
DOD	Department of Defense
DOTDS	Directorate of Training Doctrine and Simulation, U.S. Army
EMM	electronic moving map
EOS	Experimenter-Operator Station
ESIG	Evans and Sutherland Image Generator
FAA	Federal Aviation Administration
FBW	fly-by-wire
FMS	Flight Management System
FTE	flight technical error
FY	fiscal year
HelMEE	Helicopter Maneuver Envelope Enhancement
HLA	High Level Architecture
HQR	handling quality rating
HSCT	High Speed Civil Transport
HSR	High Speed Research
HUD	head-up display
Hz	Hertz
ICAB	Interchangeable Cab
ISO	International Organization for Standardization
JFK	John F. Kennedy International Airport
JSC	Johnson Space Center
JSF	Joint Strike Fighter
LARC	Langley Research Center
LASCAS	Limited-Authority Stability and Control Augmentation System
LVLASO	Low-Visibility Landing and Surface Operations
Mbps	megabits per second
MIPS	million instructions per second
MIT	Massachusetts Institute of Technology
NASA	National Aeronautics and Space Administration
NCAR	National Center for Atmospheric Research

NTSB	National Transportation Safety Board
OFZ	Obstacle Free Zone
OTW2K+	Out-the-Window 2000 Plus
PCA	Propulsion Controlled Aircraft
PIO	pilot-induced oscillation
PNN	polynomial neural network
RCAH	rate command/attitude hold
SCAS	stability and control augmentation system
SGI	Silicon Graphics Incorporated
SimFR	Simulation Fidelity Requirements
SimLab	Simulation Laboratories
SJSU	San Jose State University
SMC	structural mode control
SSV	Space Shuttle Vehicle
STOVL	short takeoff/vertical landing
TAP	Terminal Area Productivity
TCAB	Transport Cab
TCAS	Traffic Alerting and Collision Avoidance System
TERPS	Terminal Procedures
T-NASA	Taxiway Navigation and Situation Awareness
UN	United Nations
USAF	United States Air Force
USN	United States Navy
USMC	United States Marine Corps
VHF	very high frequency
VLAB	Virtual Laboratory
VME	VersaModule Eurocard
VMS	Vertical Motion Simulator

Appendix 1

A very brief description of the Aviation Systems Research, Technology, & Simulation Division facilities follows. More detailed information can be found on the world wide web at: <http://www.simlabs.arc.nasa.gov>

Boeing 747-400 Simulator

This simulator represents a cockpit of one of the most sophisticated airplanes flying today. The simulator is equipped with programmable flight displays that can be easily modified to create displays aimed at enhancing flight crew situational awareness and thus improving systems safety. The simulator also has a fully digital control loading system, a six degree-of-freedom motion system, a digital sound and aural cues system, and a fully integrated autoflight system that provides aircraft guidance and control. It is also equipped with a weather radar system simulation. The visual display system is a Flight Safety International driven by a VITAL VIIIi. The host computer driving the simulator is one of the IBM 6000 series of computers utilizing IBM's reduced instruction set computer (RISC) Technology. An additional IBM 6000 computer is provided solely for the purpose of collecting and storing data in support of experiment studies.

The 747-400 simulator provides all modes of airplane operation from cockpit preflight to parking and shutdown at destination. The simulator flight crew compartment is a fully detailed replica of a current airline cockpit. All instruments, controls, and switches operate as they do in the aircraft. All functional systems of the aircraft are simulated in accordance with aircraft data. To ensure simulator fidelity, the 747-400 simulator is maintained to the highest possible level of certification for airplane simulators as established by the Federal Aviation Administration (FAA). This ensures credibility of the results of research programs conducted in the simulator.

Advanced Concepts Flight Simulator

This unique research tool simulates a generic commercial transport aircraft employing many advanced flight systems as well as features existing in the newest aircraft being built today. The ACFS generic aircraft was formulated and sized on the basis of projected user needs beyond the year 2000. Among its advanced flight systems, the ACFS includes touch sensitive electronic checklists, advanced graphical flight displays, aircraft systems schematics, a flight management system, and a spatialized aural warning and communications system. In addition, the ACFS utilizes side stick controllers for aircraft control in the pitch and roll axes. ACFS is mounted atop a six degree-of-freedom motion system.

The ACFS utilizes SGI computers for the host system as well as graphical flight displays. The ACFS uses visual generation and presentation systems that are the same as the 747-400 simulator's. These scenes depict specific airports and their surroundings as viewed at dusk, twilight, or night from the cockpit.

Air Traffic Control Simulator

The Air Traffic Control (ATC) environment is a significant contributor to pilot workload and, therefore, to the performance of crews in flight. Full-mission simulation is greatly affected by the realism with which the ATC environment is modeled. From the crew's standpoint, this environment consists of dynamically changing verbal or data-link messages, some addressed to or generated by other aircraft flying in the immediate vicinity.

The CVSRF ATC simulator is capable of operating in three modes: stand-alone, without participation by the rest of the facility; single-cab mode, with either advanced or conventional cab participating in the study; and dual-cab mode, with both cabs participating.

Vertical Motion Simulator Complex

The VMS is a critical national resource supporting the country's most sophisticated aerospace R&D programs. The VMS complex offers three laboratories fully capable of supporting research. The dynamic and flexible research environment lends itself readily to simulation studies involving controls, guidance, displays, automation, handling qualities, flight deck systems, accident/incident investigations, and training. Other areas of research include the development of new techniques and technologies for simulation and the definition of requirements for training and research simulators.

The VMS' large amplitude motion system is capable of 60 feet of vertical travel and 40 feet of lateral or longitudinal travel. It has six independent degrees of freedom and is capable of maximum performance in all axes simultaneously. Motion base operational efficiency is enhanced by the interchangeable cab (ICAB) system. Each of the five simulation cockpits is customized, configured, and tested at a fixed-base development station and then either used in place for a fixed-base simulation or moved on to the motion platform.

Digital image generators provide full color daylight scenes and include six channels, multiple eye points, and a chase plane point of view. The VMS simulation lab maintains a large inventory of customizable visual scenes with a unique in-house capability to design, develop and modify these databases. Real-time aircraft status information can be displayed to both pilot and researcher through a wide variety of analog instruments, and head-up, head-down or helmet-mounted displays.

For additional information, please contact

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